PART IV

Composite Types

Gopher Level

Intermediate

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PART IV

Composite Types

Arrays ✓

Collection
of
Elements
Indexable
Fixed Length

Slices

Collection
of
Elements
Indexable
Dynamic length

String Internals

Byte Slices
ASCII & Unicode
Encoding & Decoding

Maps

Collection
of
Indexable
Key-Value Pairs

Structs

Groups
different types of
variables together

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PART IV

Composite Types

✓

Arrays

Collection
of
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ASCII & Unicode
Encoding & Decoding

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Collection
of
Indexable
Key-Value Pairs

Structs

Groups
different types of
variables together

A slice doesn't contain any elements on its own;
It's just a view into an array.

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SLICES

What you're going to learn in this section?

- ★ Slices vs Arrays
- ★ Growing — append()
- ★ Slicing — Slice Expressions *[low:high]*
- ★ Internals
  - ★ Backing Array
  - ★ Slice Header
  - ★ Capacity of a Slice — cap()
- ★ Full Slice Expressions *[low:high:cap]*
- ★ Preallocation — make()
- ★ Copying slices without a loop — copy()
- ★ Multi-Dimensional Slices

SLICES

You're going to build awesome projects again!

EMPTY FILE FINDER

Your first taste of file operations

```
$ go run main.go ~/files
Empty files in "~/files":
empty file 1
empty file 2
```

→ out.txt

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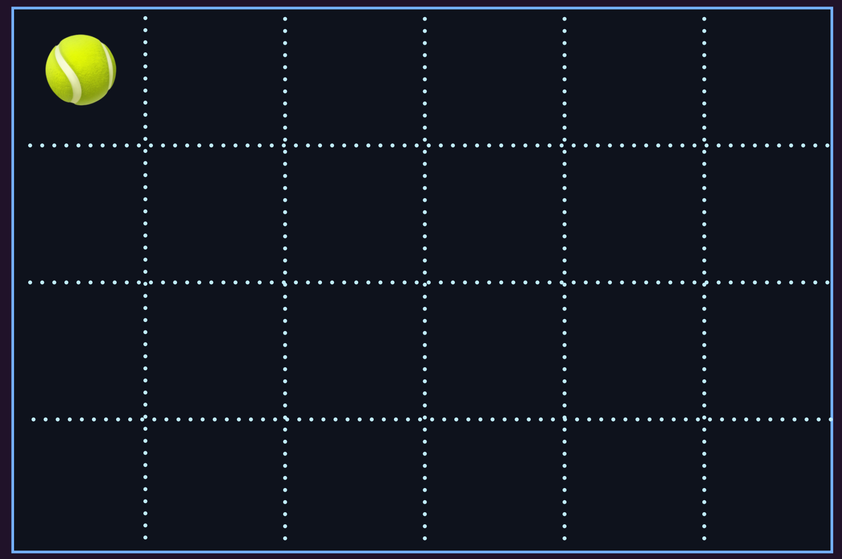
SLICES

You're going to build awesome projects again!

BOUNCING BALL



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SLICES vs ARRAYS

Let's talk about the differences between slices and arrays

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Why?

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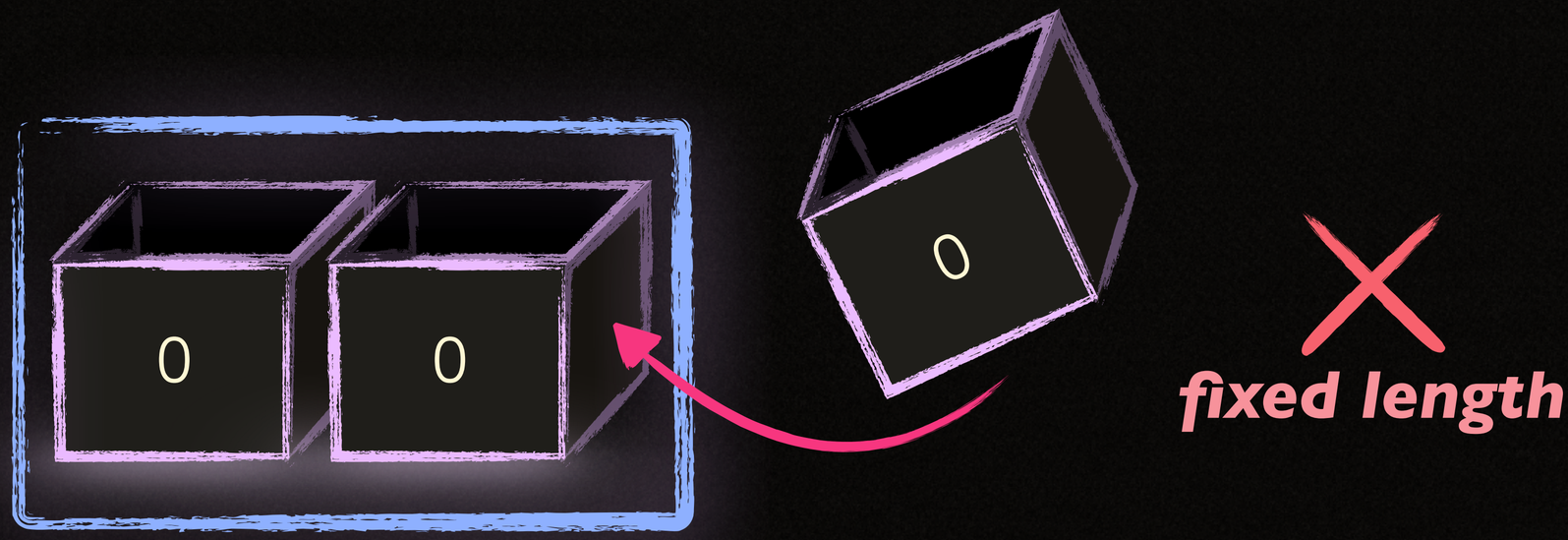
ARRAYS

Arrays cannot grow or shrink



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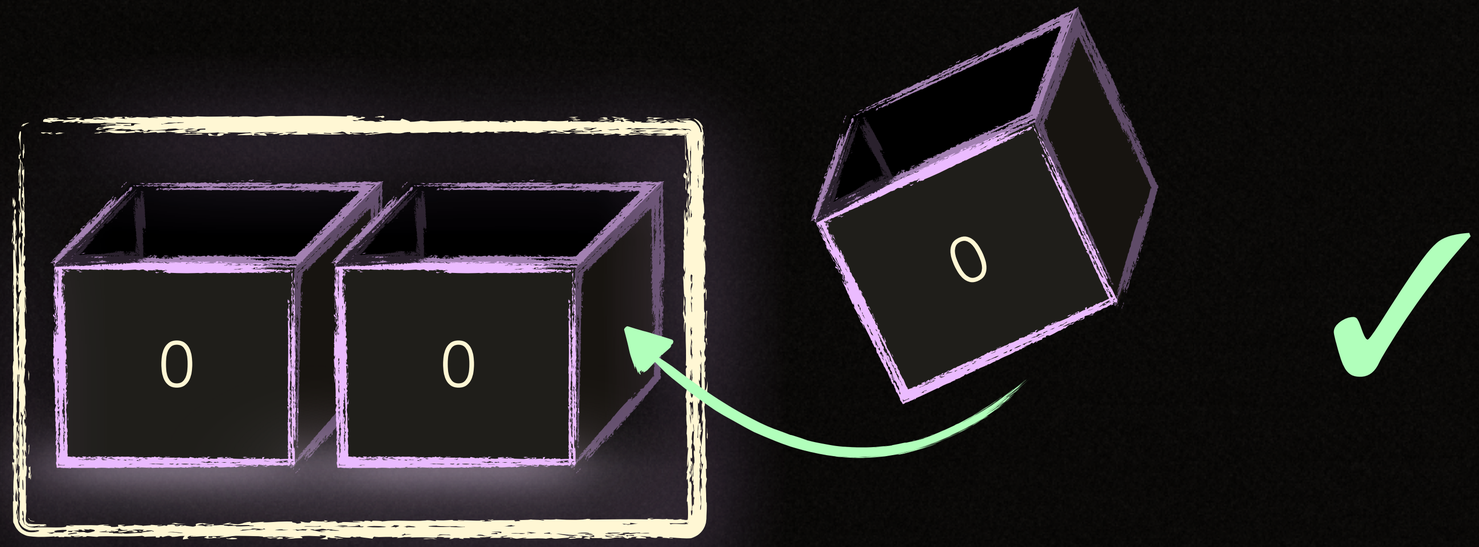
SLICES

Slices can grow and shrink in runtime



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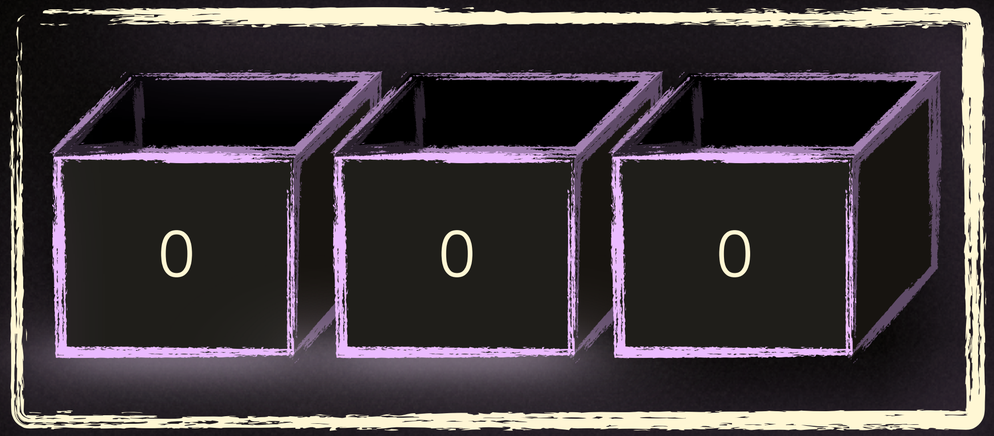
SLICES

Slices can grow and shrink in runtime



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ARRAY

You cannot add or remove elements to/from an array in runtime

```
var nums [2]int
```

Its length is part of its type

- ✗ Its length belongs to compile-time
- ✗ So its length cannot change in runtime
- ✗ So it cannot grow or shrink

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SLICE

You can add or remove elements to/from a slice in runtime

```
var nums []int
```

It doesn't have a fixed length at *compile-time*

✓ So it can grow and shrink in runtime

✓ Its length belongs to runtime

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ARRAY'S ZERO VALUE

Go automatically sets uninitialized array elements to their Zero Values

```
var nums [5]int
```

nums is [0, 0, 0, 0, 0]

len(nums) is equal to 5

It always have the same number of elements

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SLICE'S ZERO VALUE

Unlike an array, a slice's zero value is nil

```
var nums []int
```

nums is nil

len(nums) is equal to 0

It doesn't contain any elements yet

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NIL SLICE

You cannot get and set non-existing elements from/to a nil slice

```
var nums []int

nums[0]  ⟶  ✗
nums[1]  ⟶  ✗
len(hello)  ⟶  0  ✓
```

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SLICES vs ARRAYS

Slices are dynamic — Arrays are fixed

SLICE

```
var nums []int
```

Its length is *not* part of its type

It can grow and shrink

Its zero value is nil

ARRAY

```
var nums [2]int
```

Its length is part of its type

It cannot grow or shrink

Its zero value is zero valued elements

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SLICES & ARRAYS

Common properties

SLICE

```
var nums []int
```

ARRAY

```
var nums [2]int
```

They can only contain the same type of elements

nums[0]

nums[1]

len(nums)

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APPEND

Time to grow up!

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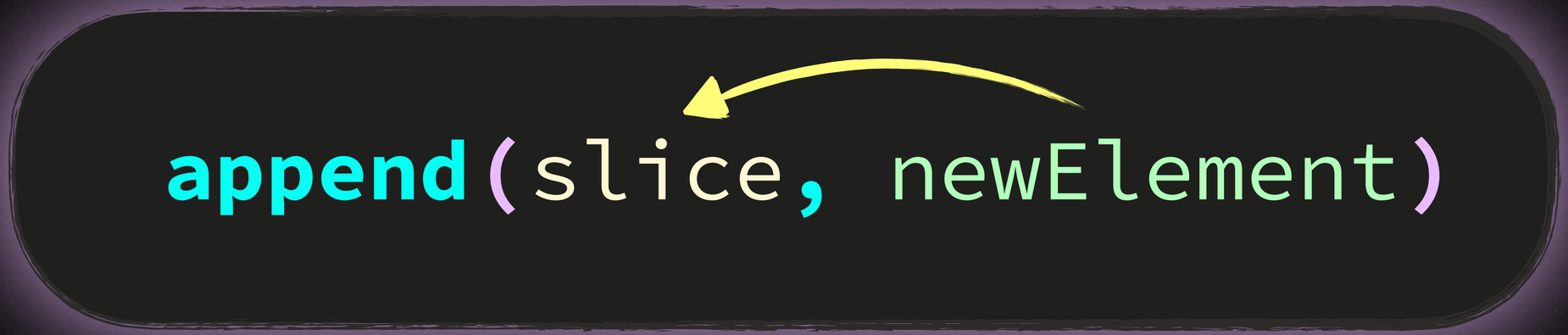
APPEND

Appends a new element to a slice



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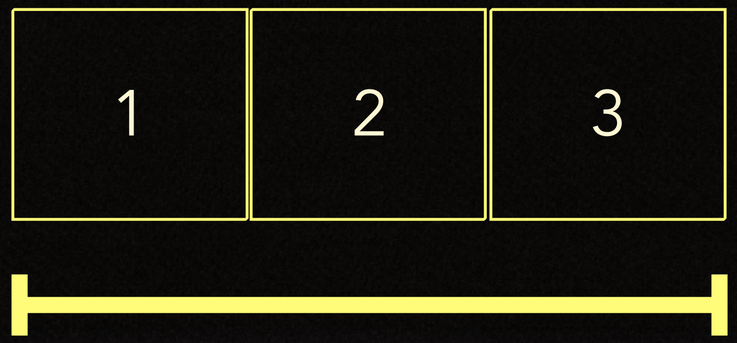
APPEND

Appends a new element to a slice




```
nums := []int{1, 2, 3}
append(nums, 4)
```

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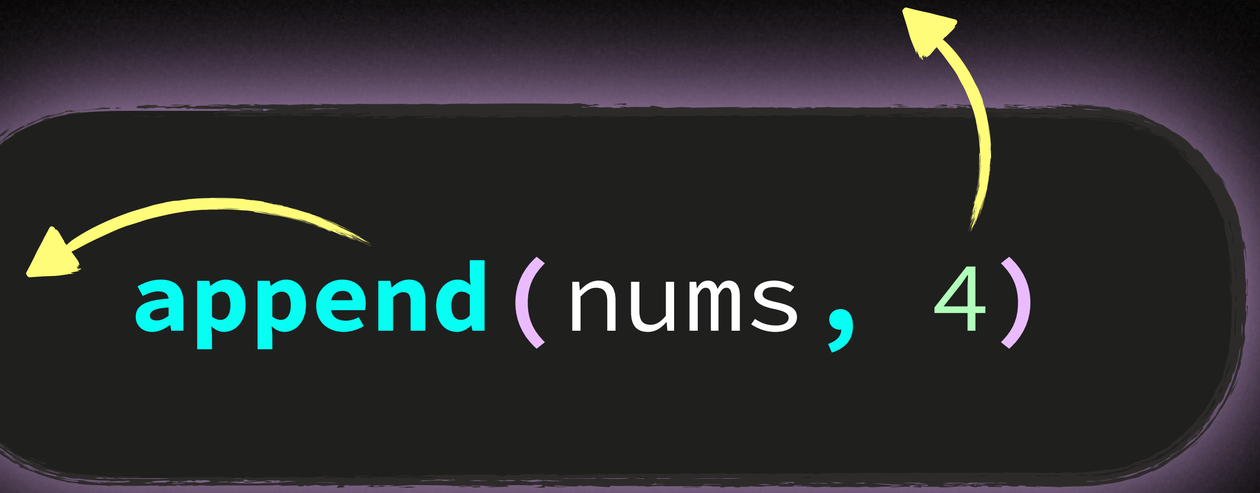
APPEND

Appends an element to a slice and returns a new slice

appends it to a new slice



append can't change the passed slice

Instead: It returns **a new slice**

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APPEND

Appends an element to a slice and returns a new slice

append returns a new slice

Here, I'm **saving** it **back** to the **nums slice**

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APPEND

Appends an element to a slice and returns a new slice

```
nums := []int{1, 2, 3}
nums = append(nums, 4)
```

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APPEND

Appends an element to a slice and returns a new slice

```
nums := []int{1, 2, 3}
nums = append(nums, 4)
nums = append(nums, 9)
```

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APPEND

Appends new elements to the back

```
nums := []int{1, 2, 3}
nums = append(nums, 4)
nums = append(nums, 9)
```

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APPEND

It can append multiple elements — append is a variadic function

```
nums := []int{1, 2, 3}
nums = append(nums, 4, 9)
```

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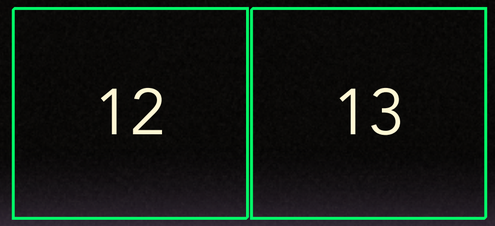
APPEND

Ellipsis allows you to append a slice to another slice




```
nums := []int{1, 2, 3}
tens := []int{12, 13}
nums = append(nums, tens...)
```

```
append(nums, 12, 13)
```

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SLICE EXPRESSIONS

Let's cut that slice!

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SLICEABLE = Any value that can be sliced

SLICE

ARRAY

STRING

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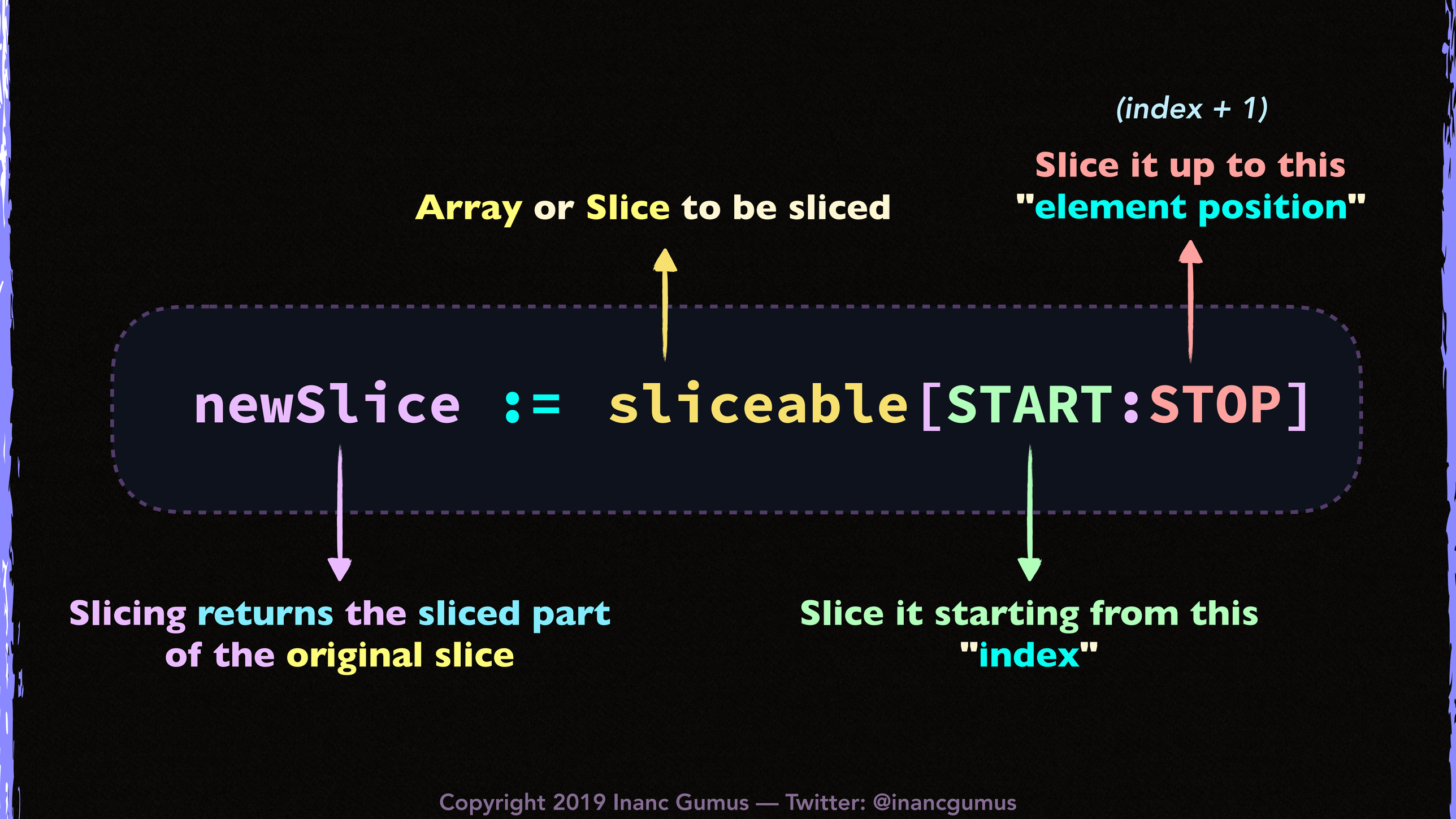
(index + 1)
Slice it up to this "element position"
Array or Slice to be sliced
newSlice := sliceable[START:STOP]
Slicing returns the sliced part of the original slice
Slice it starting from this "index"

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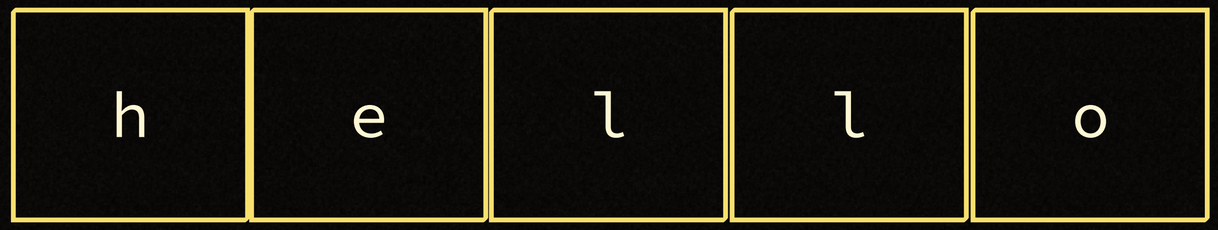
SLICE EXPRESSIONS

Slicing creates a new slice by cutting a sliceable

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```



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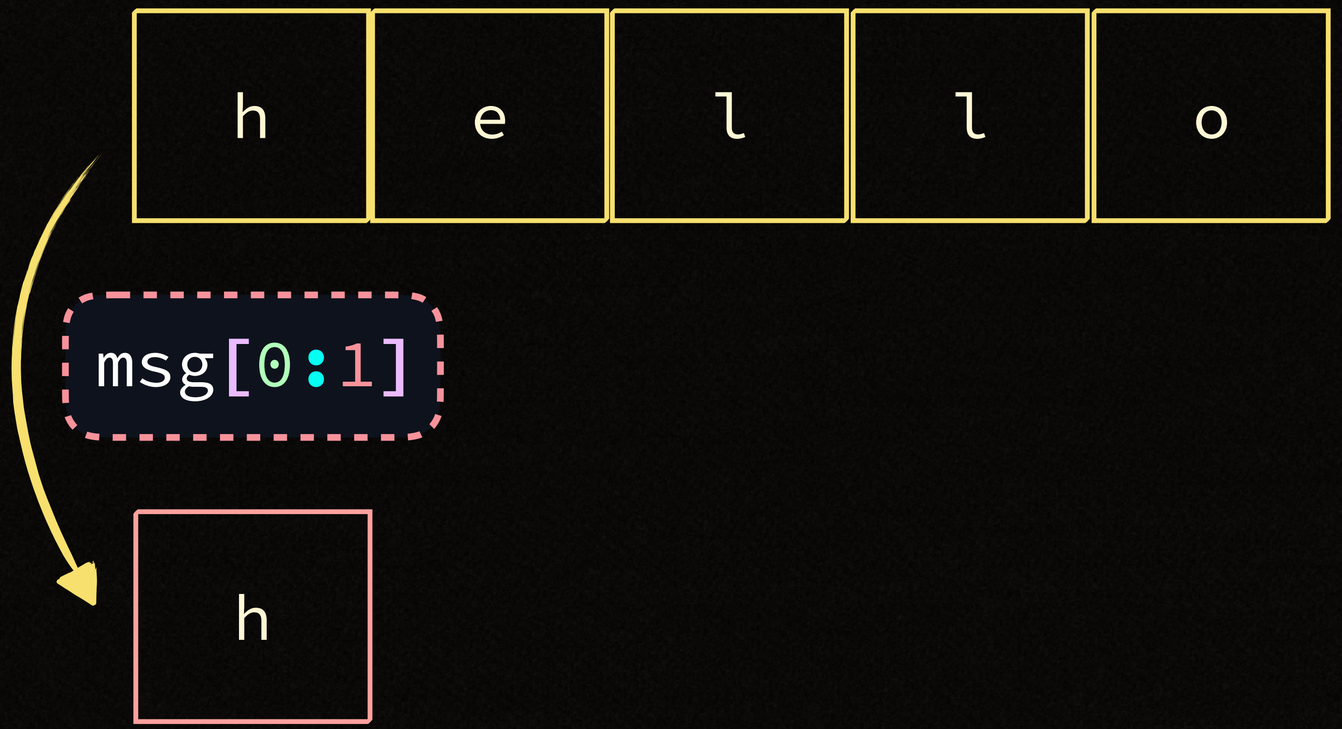
SLICE EXPRESSIONS

Creates a new slice from 0th index to the first element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```



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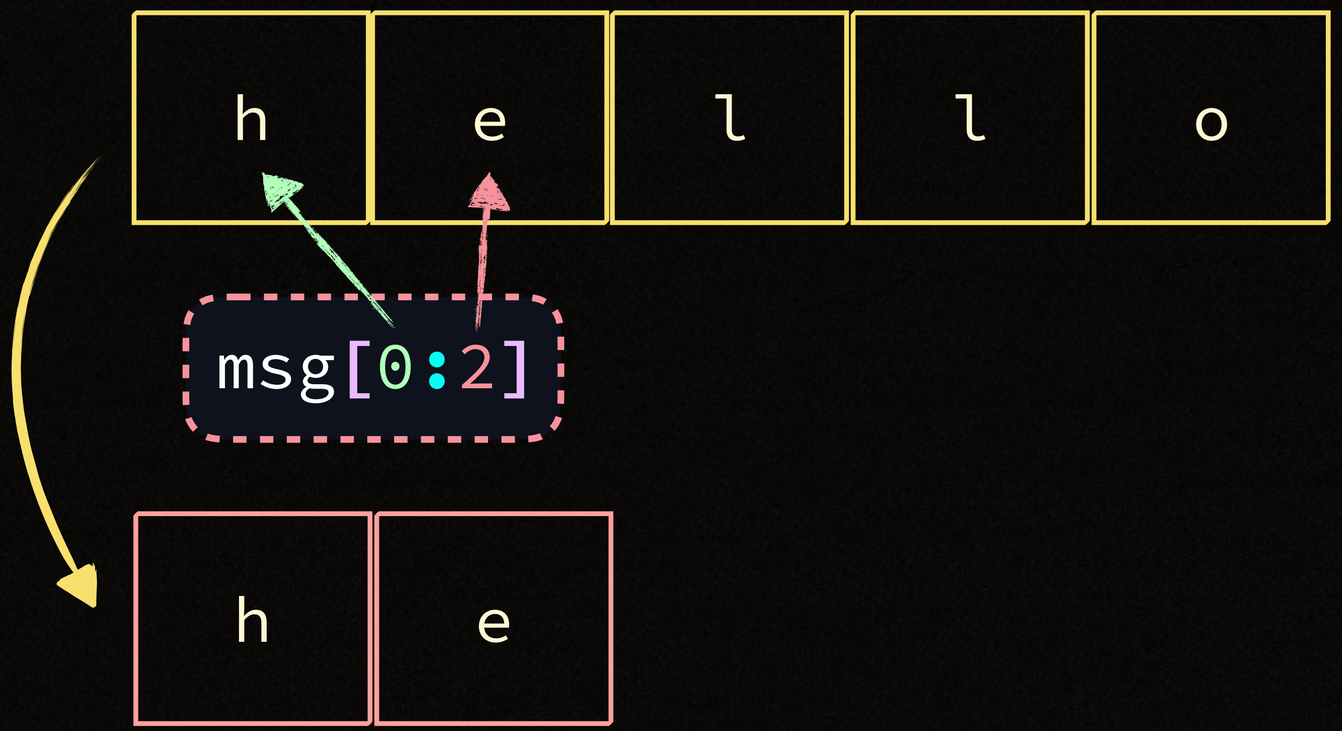
SLICE EXPRESSIONS

Creates a new slice from 0th index to the 2nd element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```



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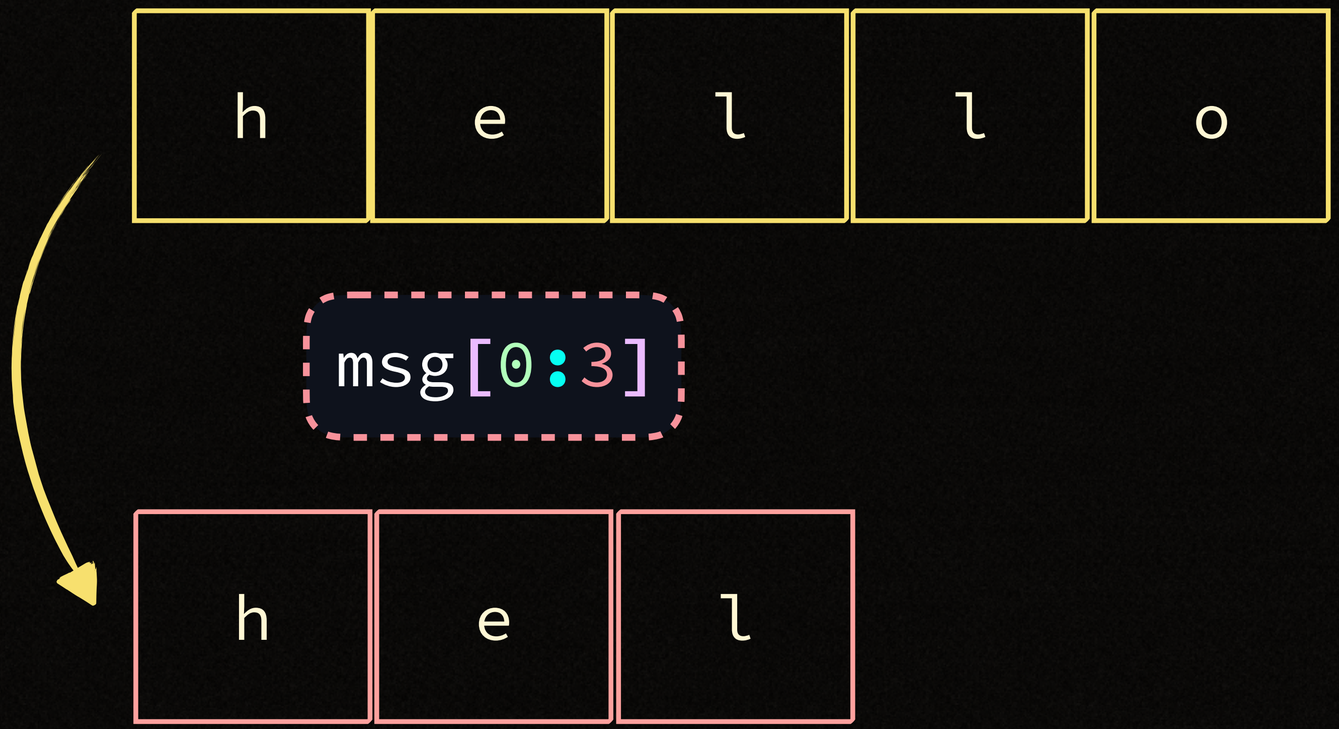
SLICE EXPRESSIONS

Creates a new slice from 0th index to the 3rd element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```



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SLICE EXPRESSIONS

Creates a new slice from 0th index to the 4th element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```

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SLICE EXPRESSIONS

Creates a new slice from 0th index to the last element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```

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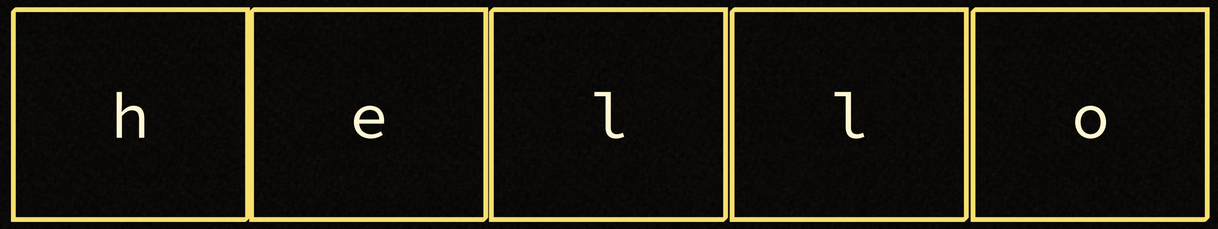
SLICE EXPRESSIONS

You cannot slice a slice beyond its length *(not completely true)*

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```




```
msg[:6]
```

Runtime Error

Slice bounds out of range

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SLICE EXPRESSIONS

Creates a new slice from 1st index to the 4th element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```

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SLICE EXPRESSIONS

Creates a new slice from 1st index to the last element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```

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SLICE EXPRESSIONS

Creates a new slice from 0th index to the 4th element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```

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APPEND

Appending to a slice appends after the last element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```

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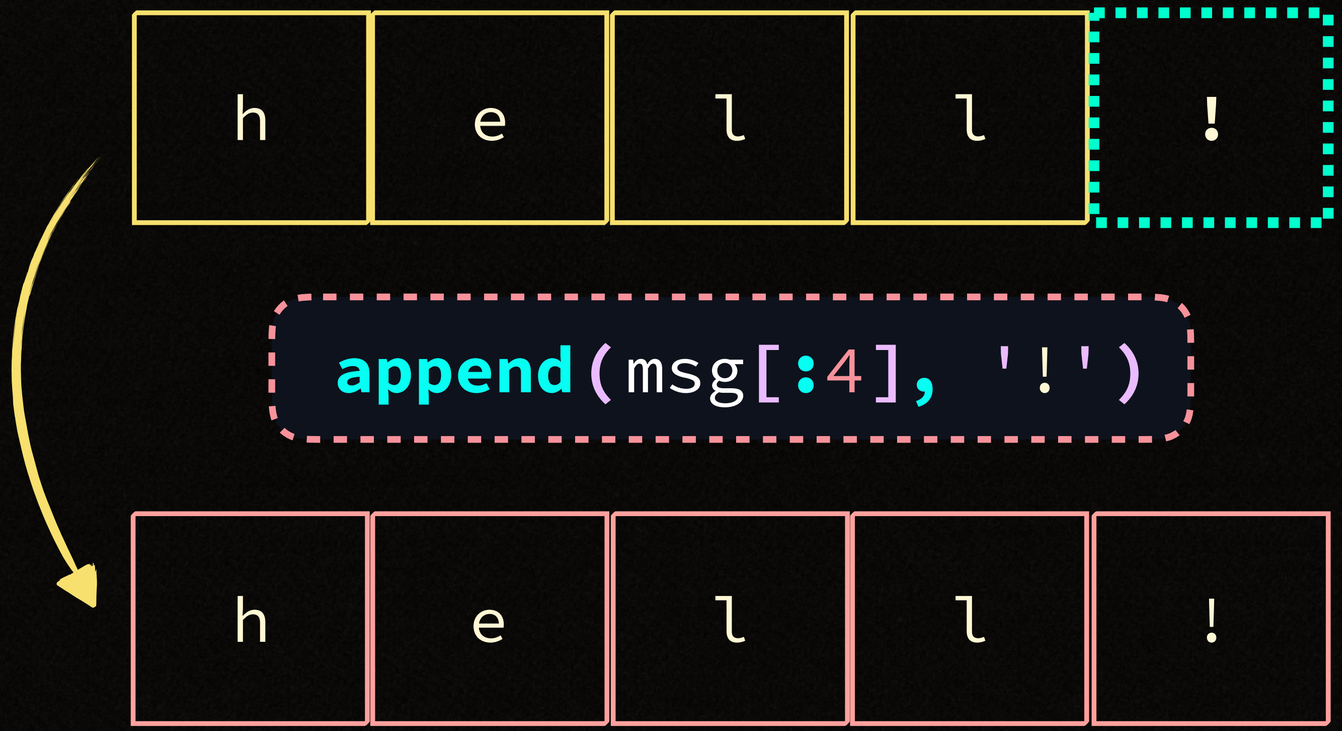
APPEND

Appending to a sliced slice overwrites the original slice

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```



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SLICE INTERNALS

BACKING ARRAY OF A SLICE

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BACKING ARRAY

A slice doesn't *directly* store any elements

```
ages := []int{35, 15, 25}
```

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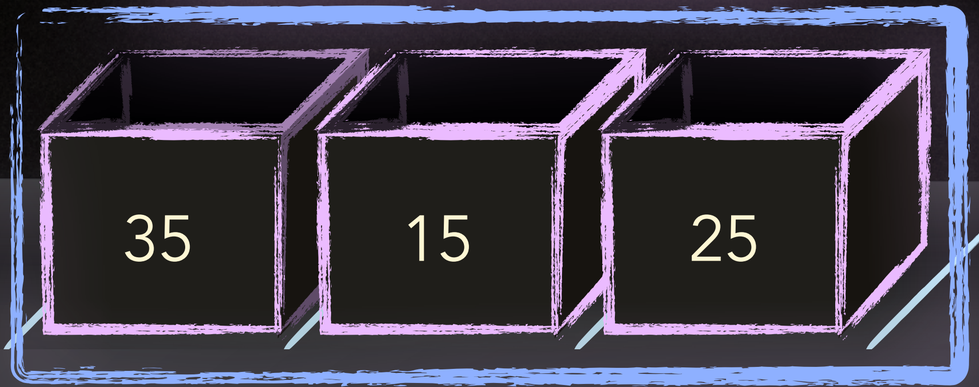
BACKING ARRAY

Slice literal creates a hidden array and returns a slice that refers to that array

```
ages := []int{35, 15, 25}
```

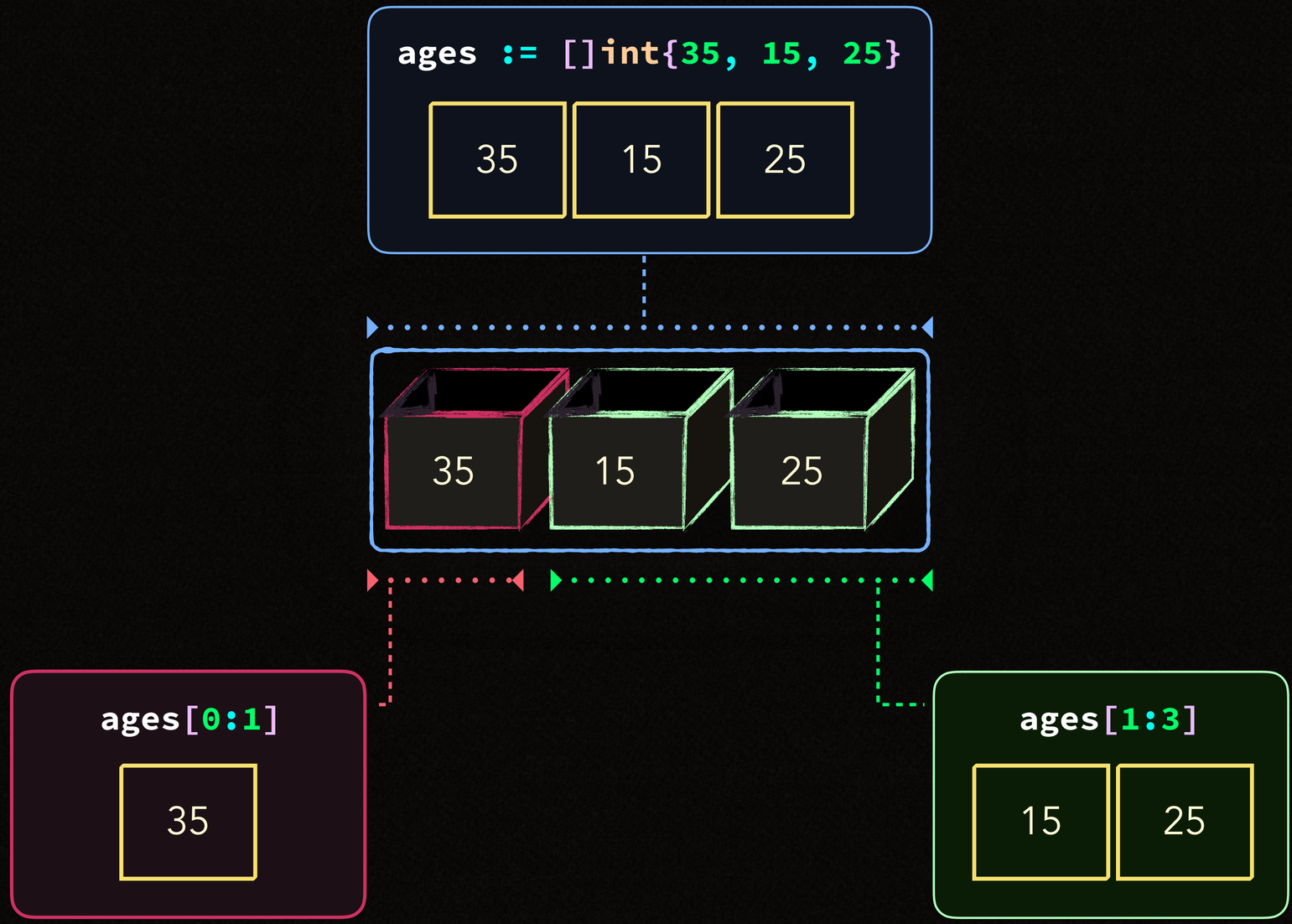
BACKING ARRAY



the real storage stored separately from the slice

BACKING ARRAY

A slice is a window to its backing array



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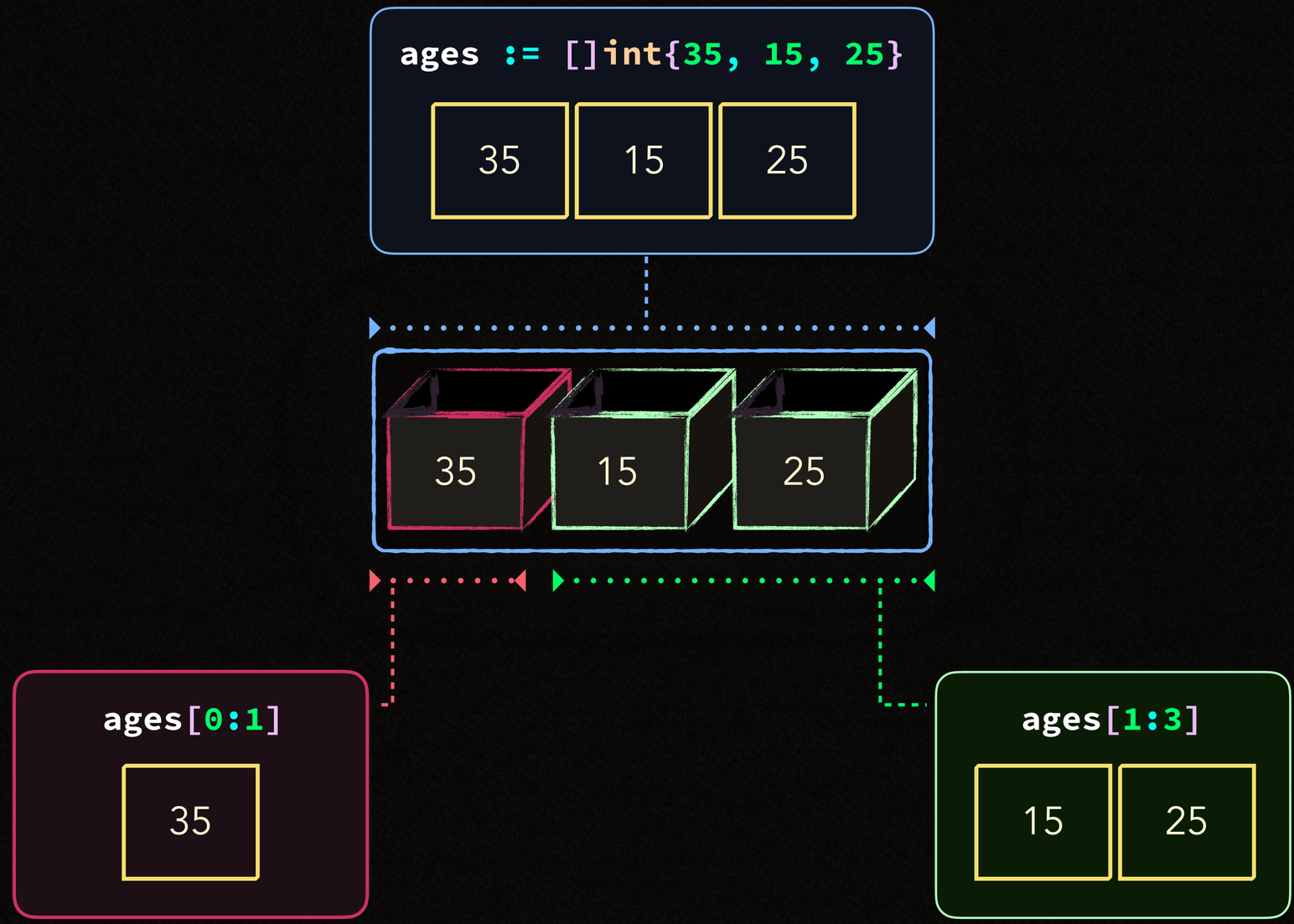
BACKING ARRAY

A slice created with a slice expression share the same array with the original slice



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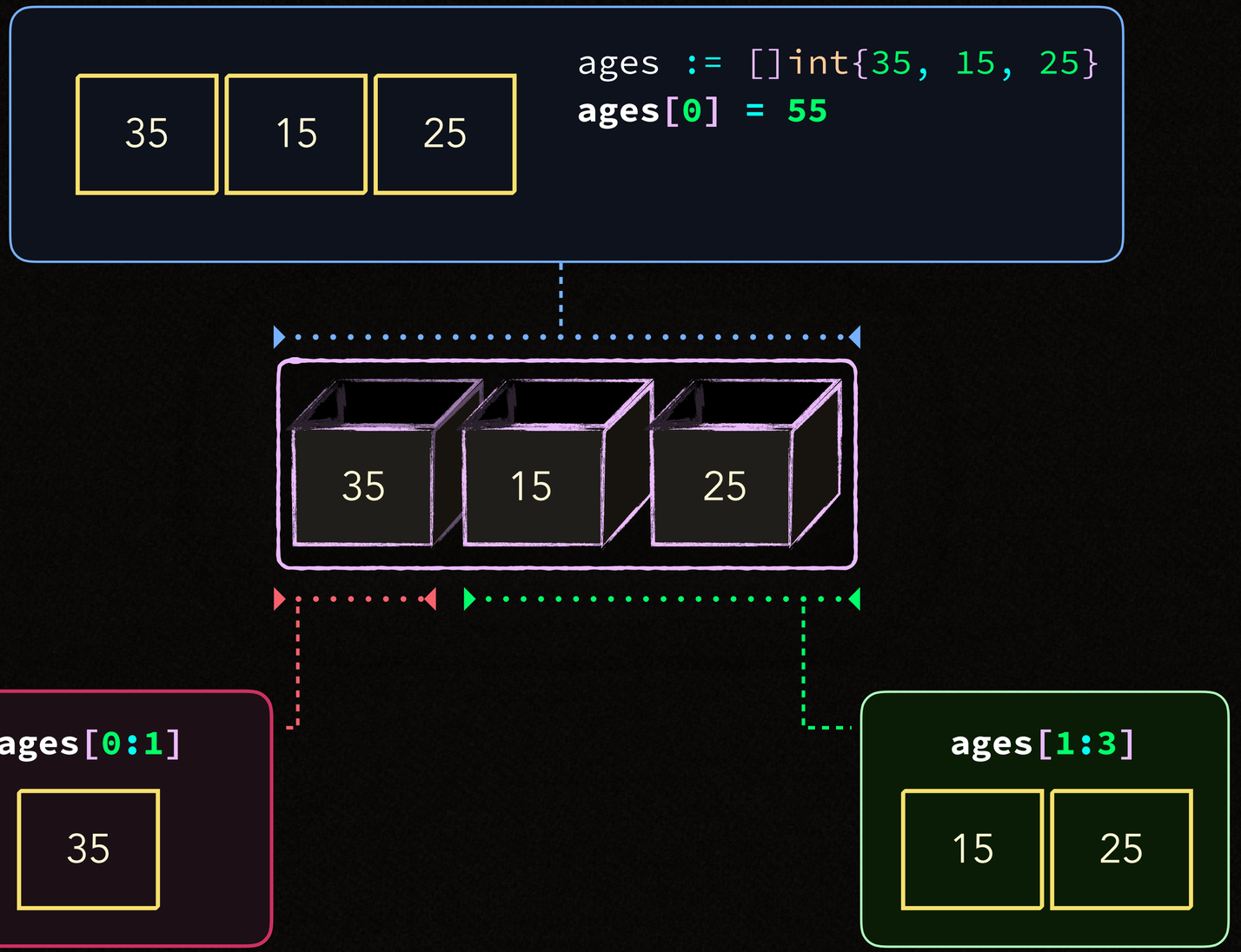
BACKING ARRAY

Slices see the changes in the shared backing array



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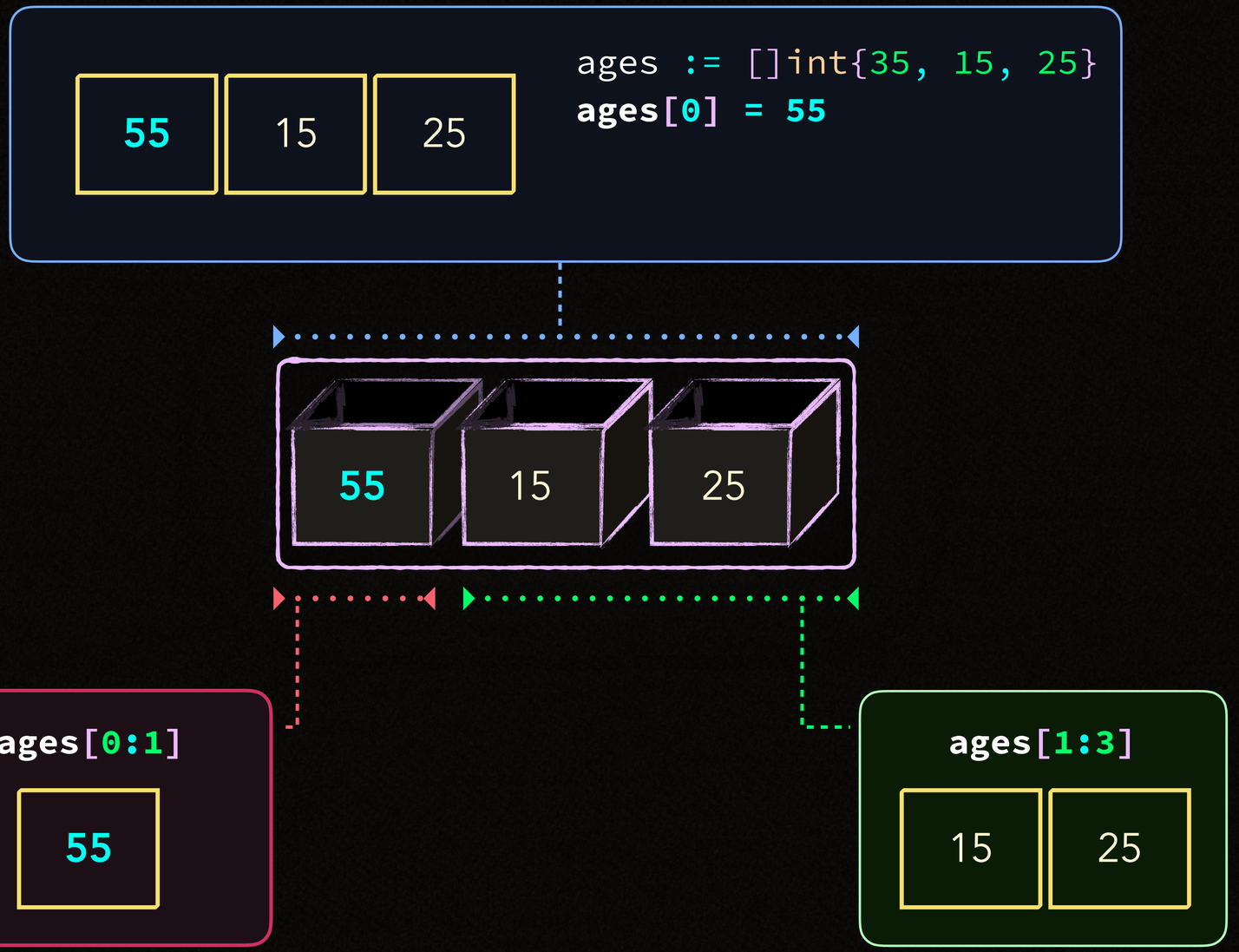
BACKING ARRAY

Slices see the changes in the shared backing array



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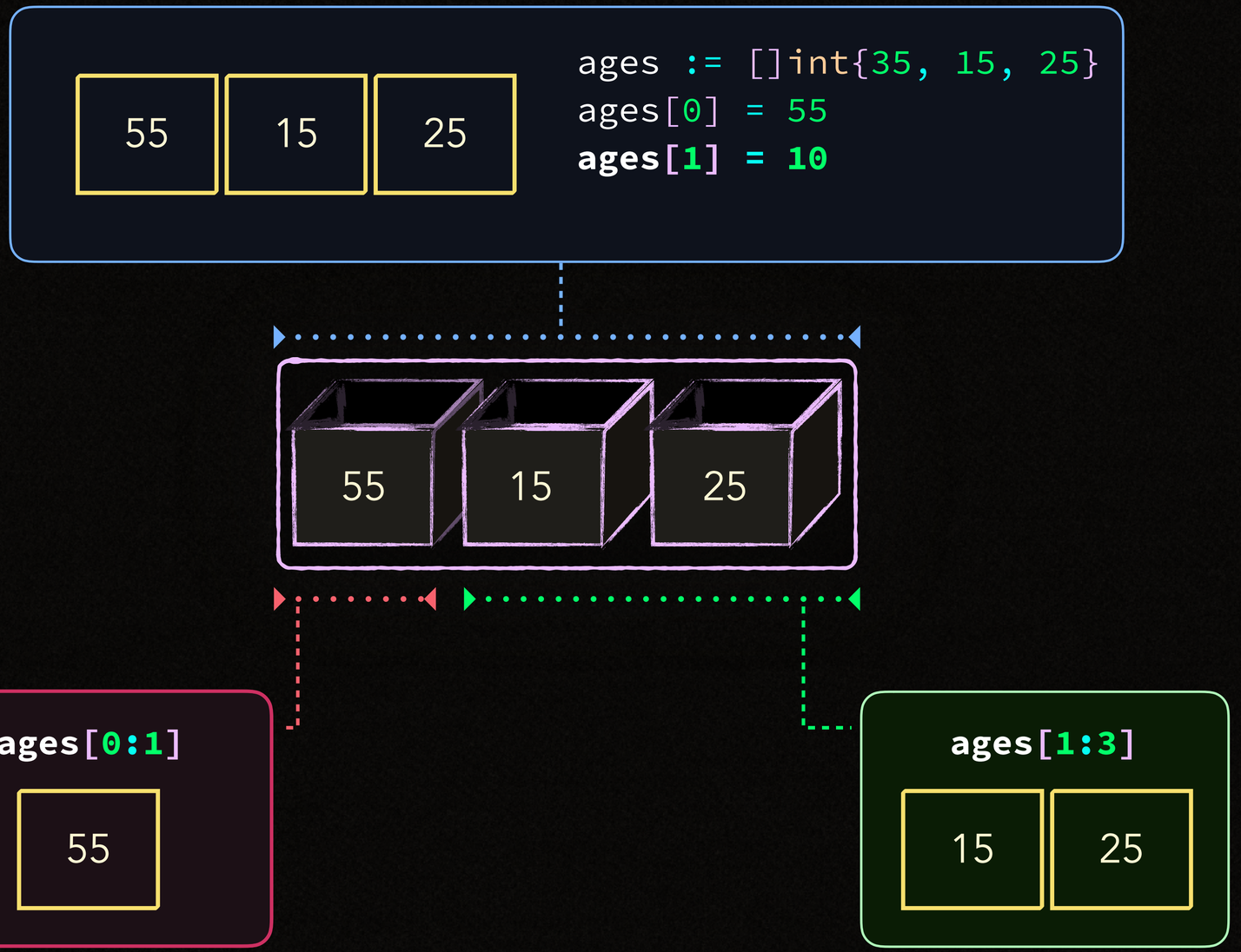
BACKING ARRAY

Slices see the changes in the shared backing array



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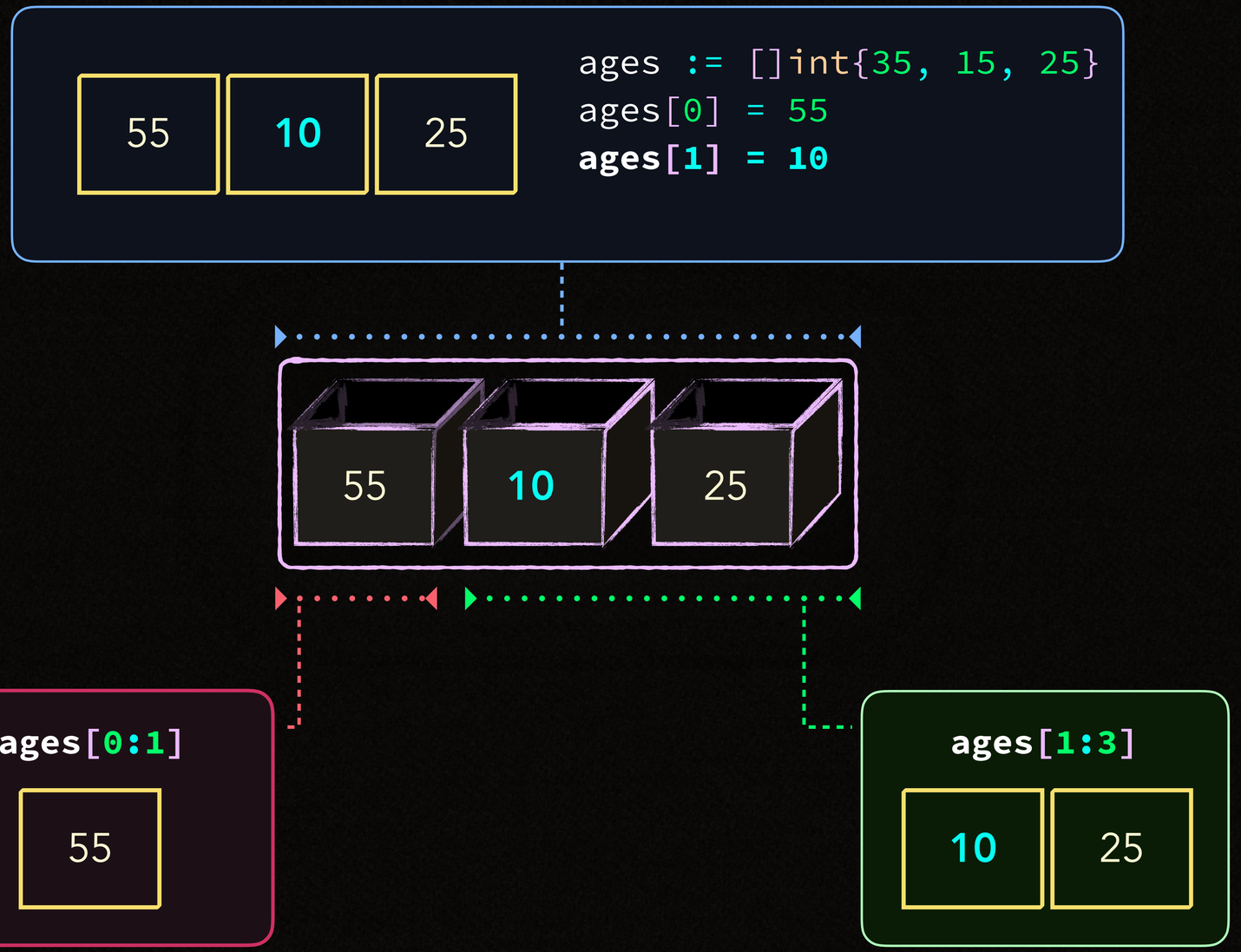
BACKING ARRAY

Slices see the changes in the shared backing array



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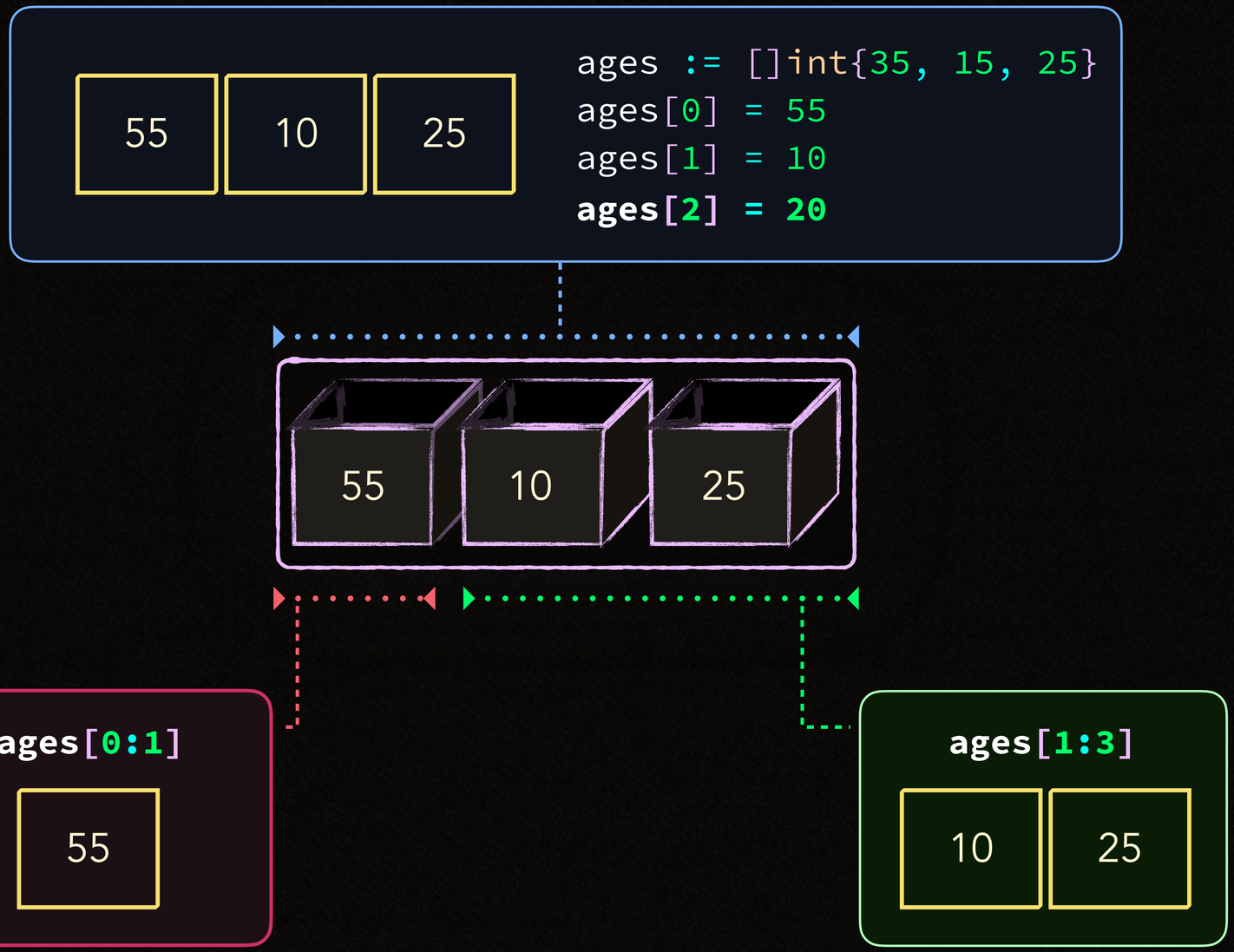
BACKING ARRAY

Slices see the changes in the shared backing array



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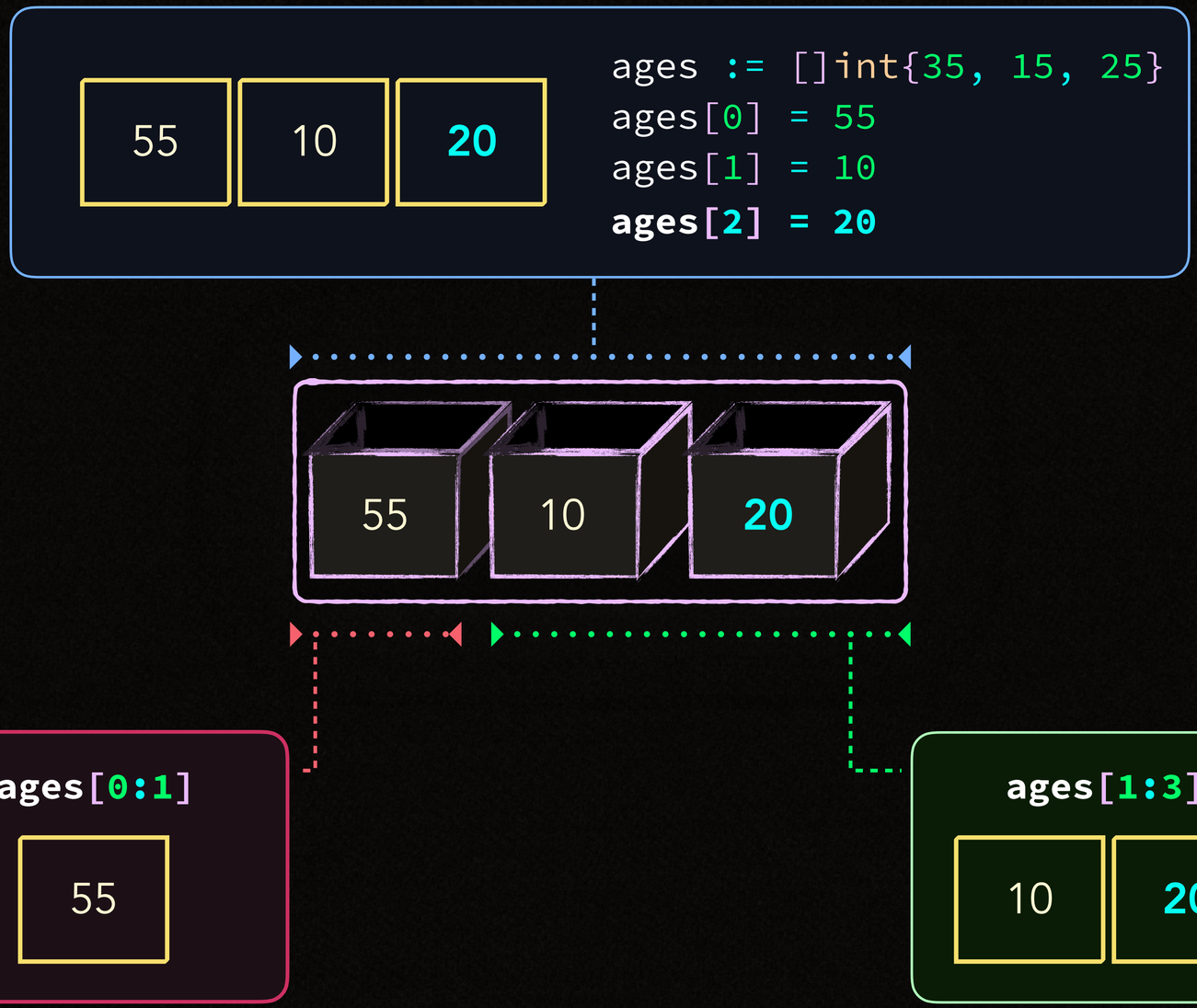
BACKING ARRAY

Slices see the changes in the shared backing array



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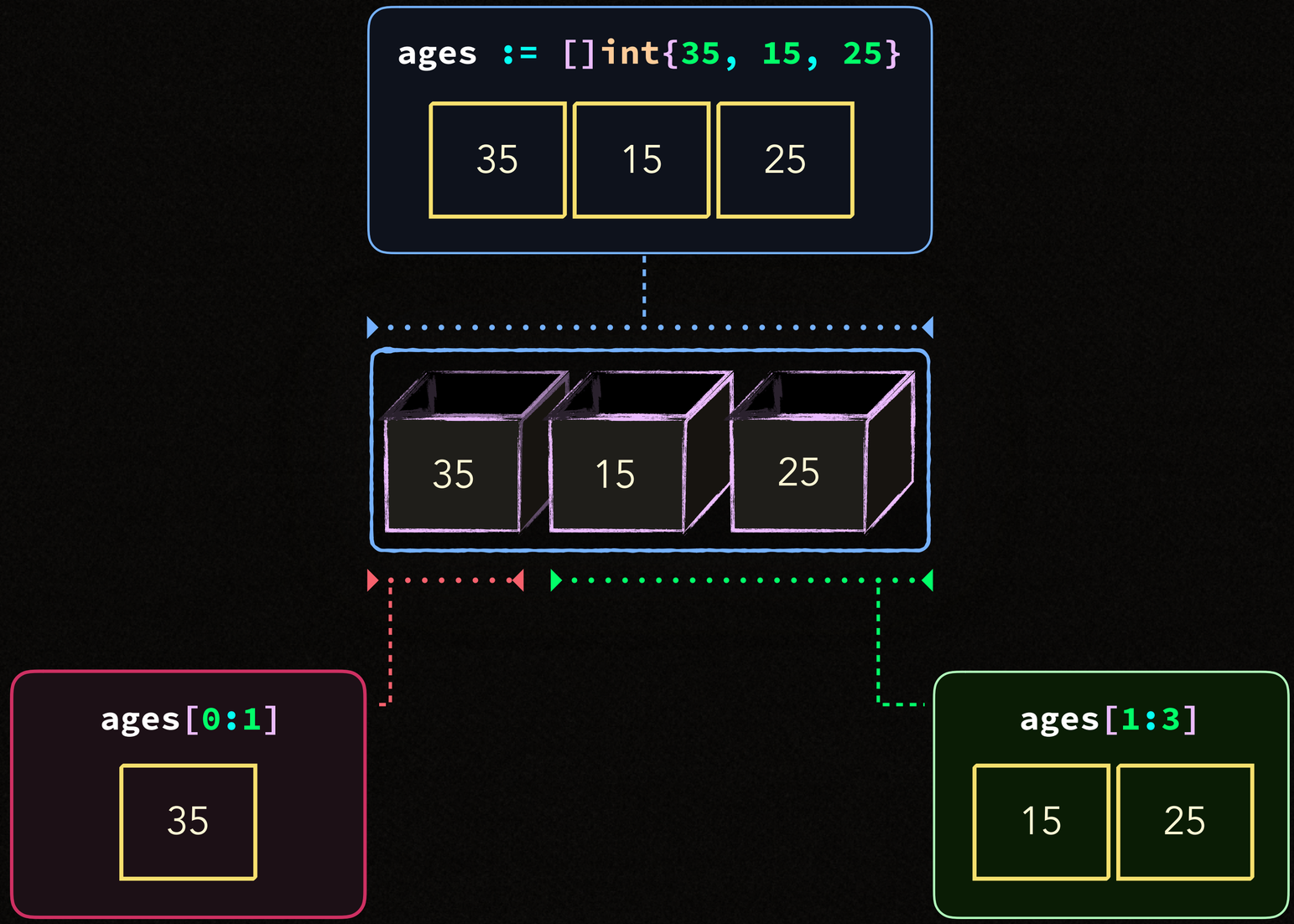
BACKING ARRAY

Slicing is cheap because of the same backing array is used



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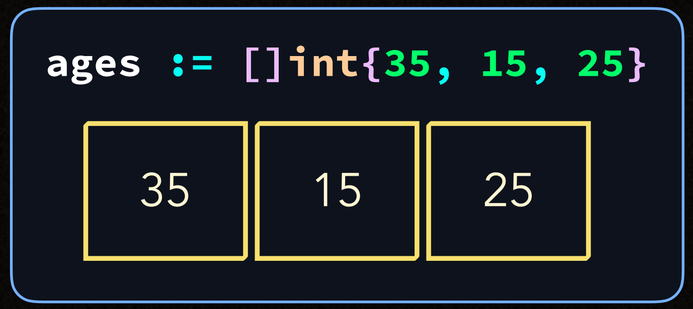
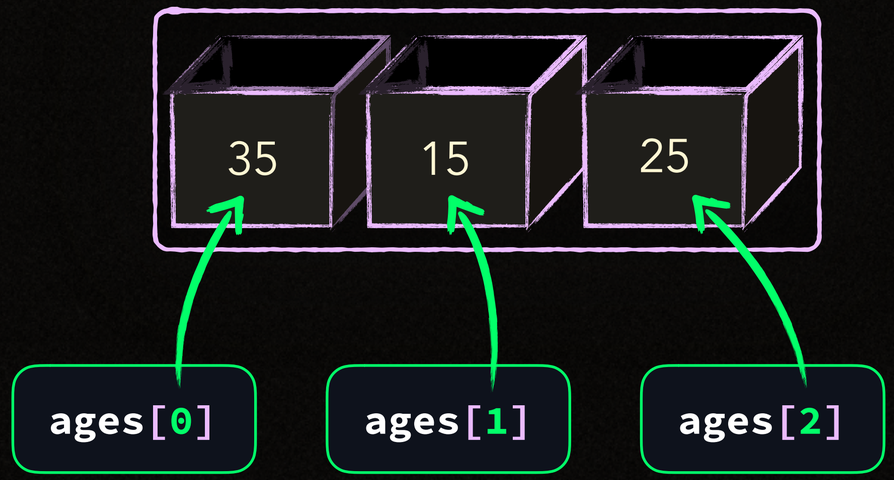
BACKING ARRAY

Indexing a slice is fast because the slice's backing array is contiguous in memory





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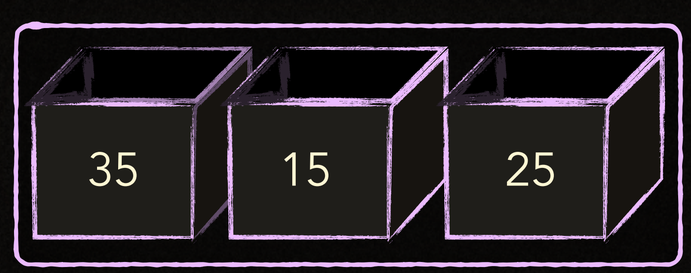
BACKING ARRAY

Slices can have separate backing arrays

```
ages := []int{35, 15, 25}
```



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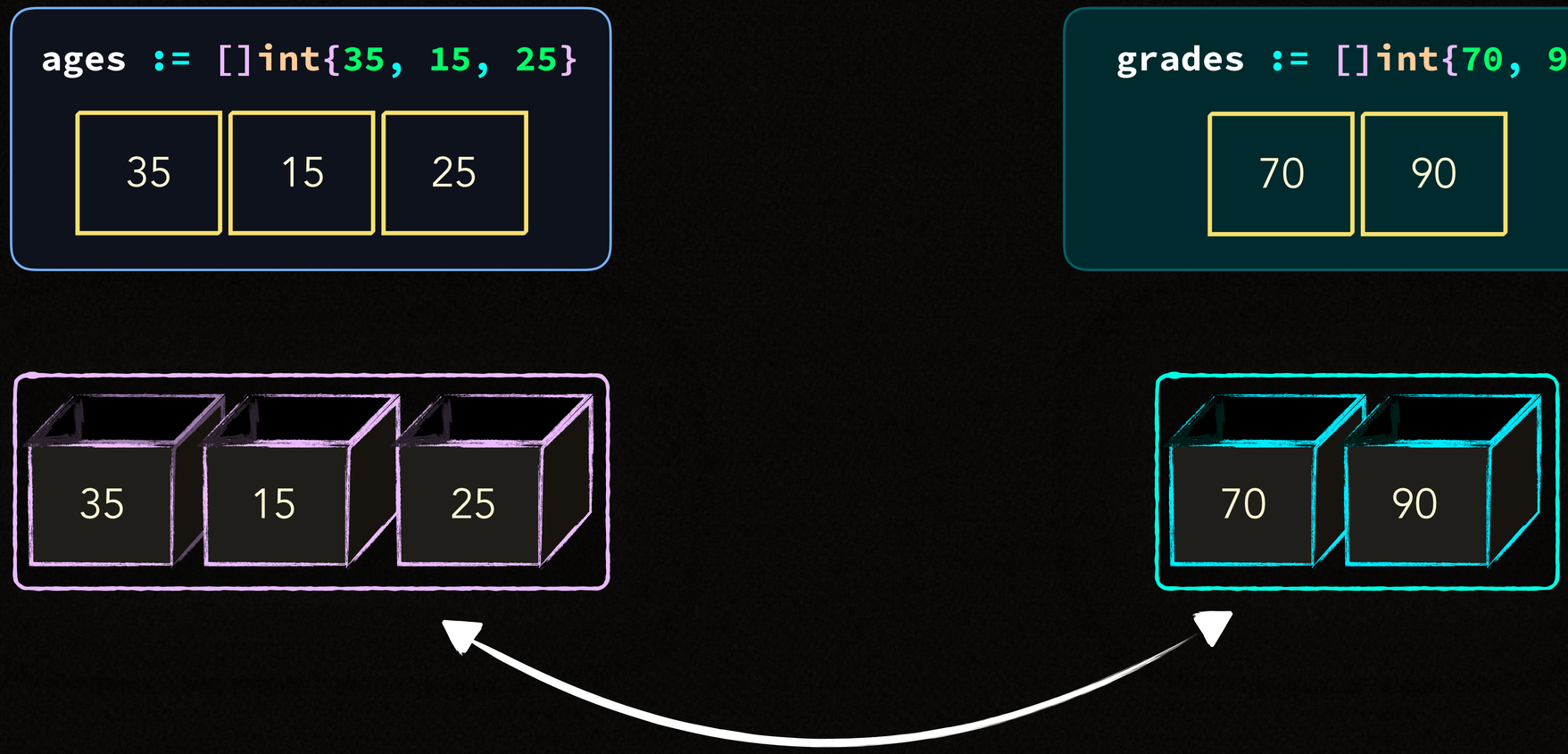
BACKING ARRAY

A non-empty slice literal always creates a new backing array



These slices have separate backing arrays

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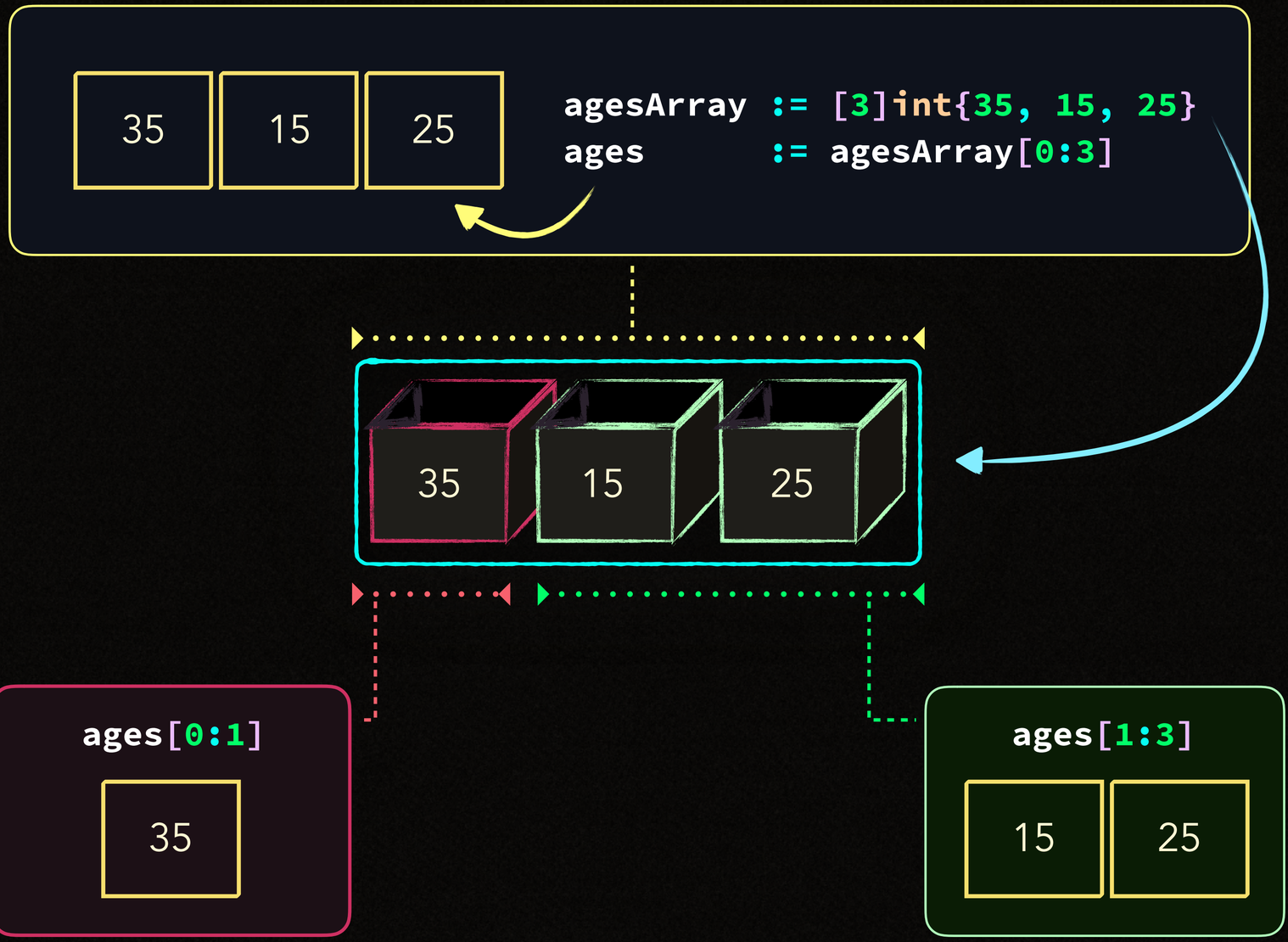
BACKING ARRAY

A "sliced array" becomes the backing array of the returned slice



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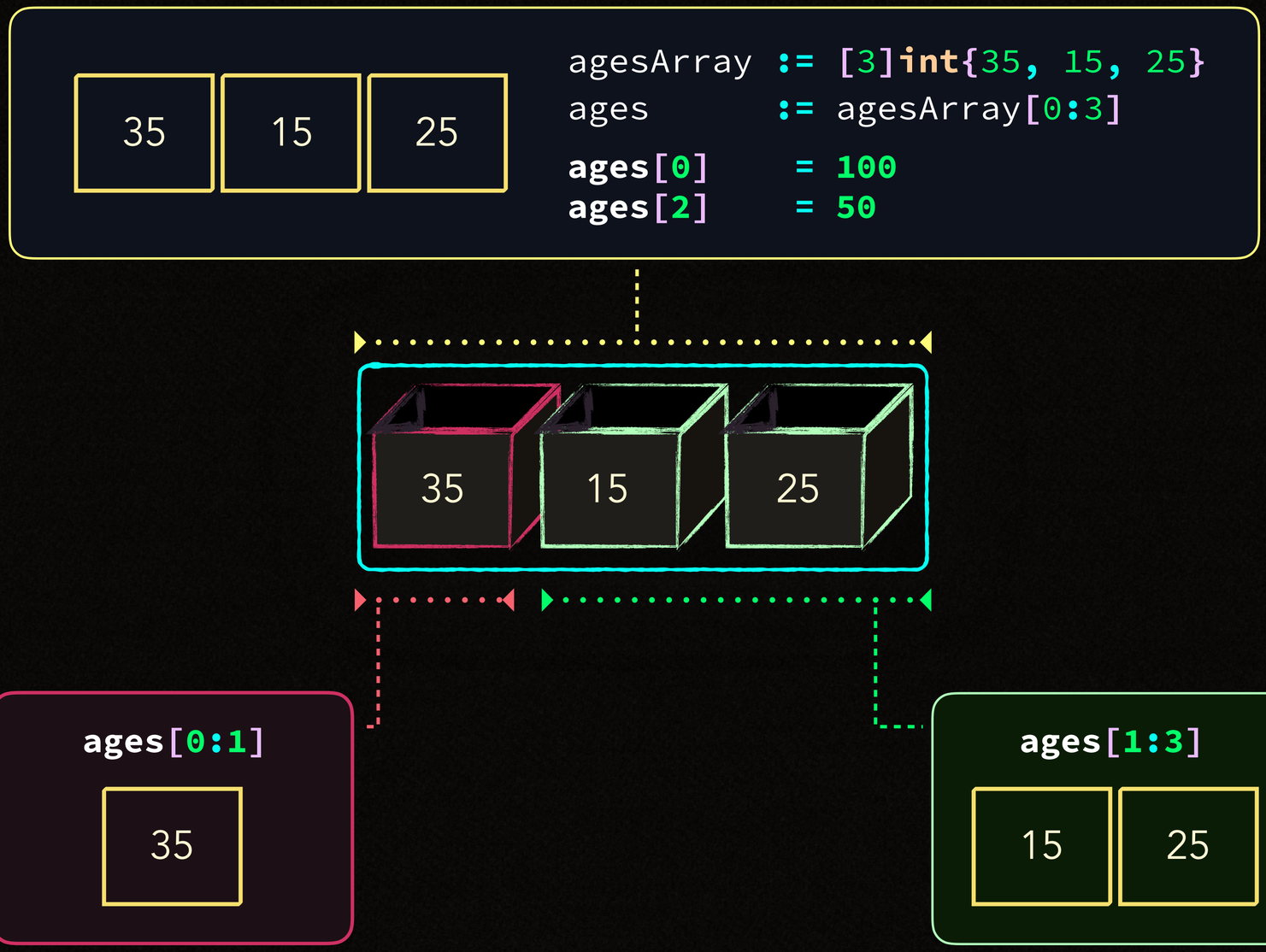
BACKING ARRAY

A "sliced array" becomes the backing array of the returned slice



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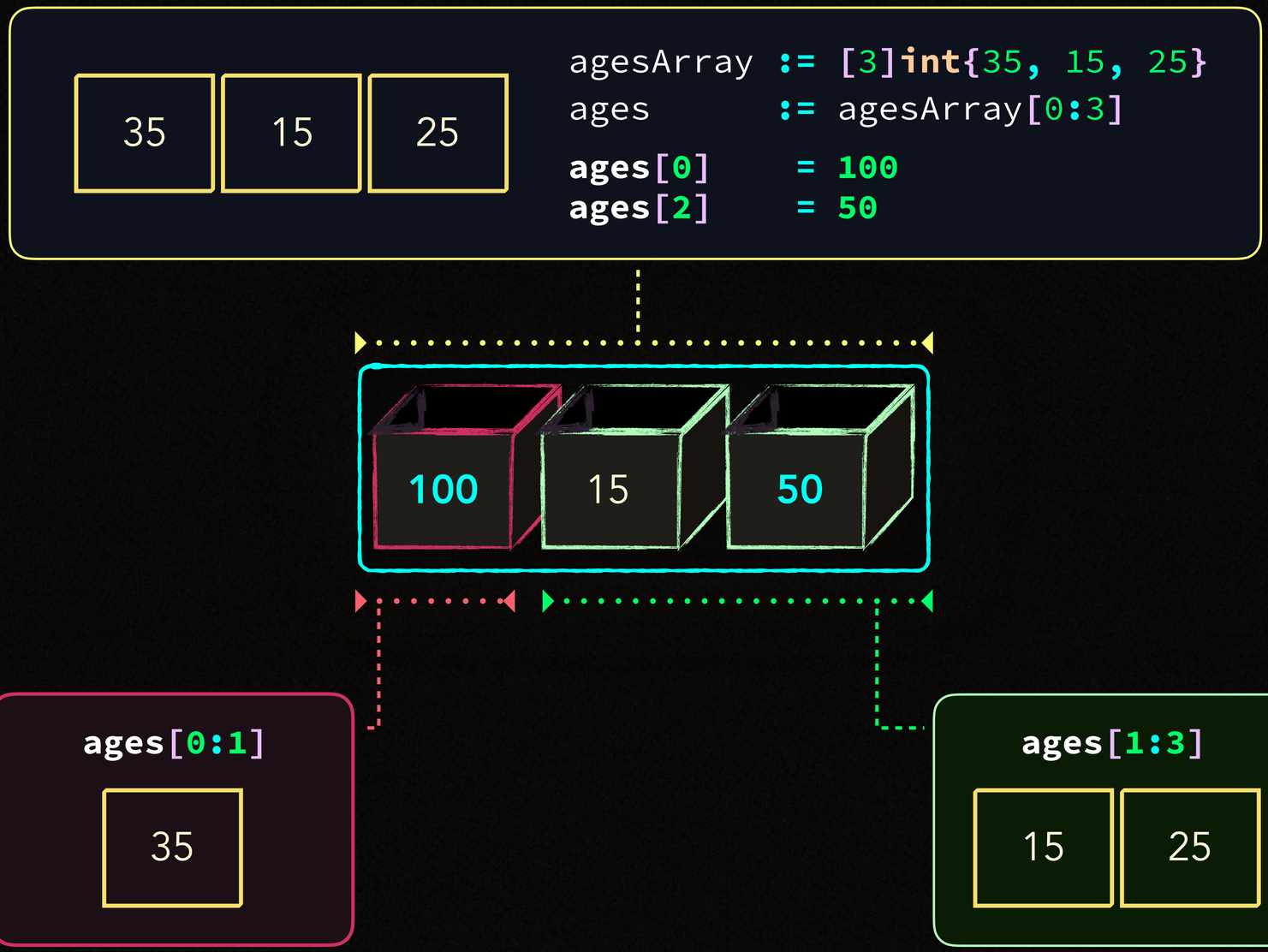
BACKING ARRAY

A sliced array is shared among the slices as their backing array



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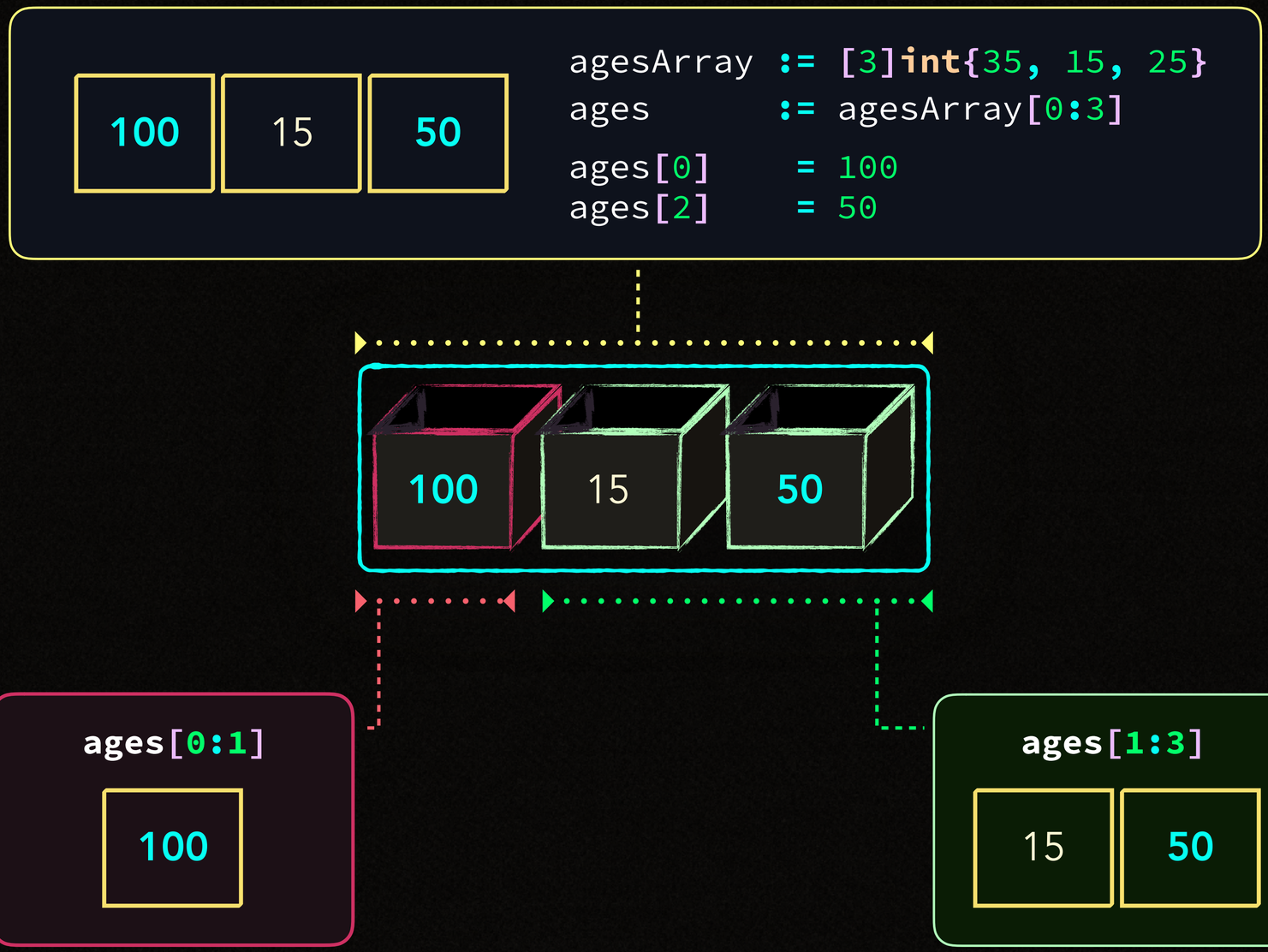
BACKING ARRAY

A sliced array is shared among the slices as their backing array



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SLICE INTERNALS

SLICE HEADER

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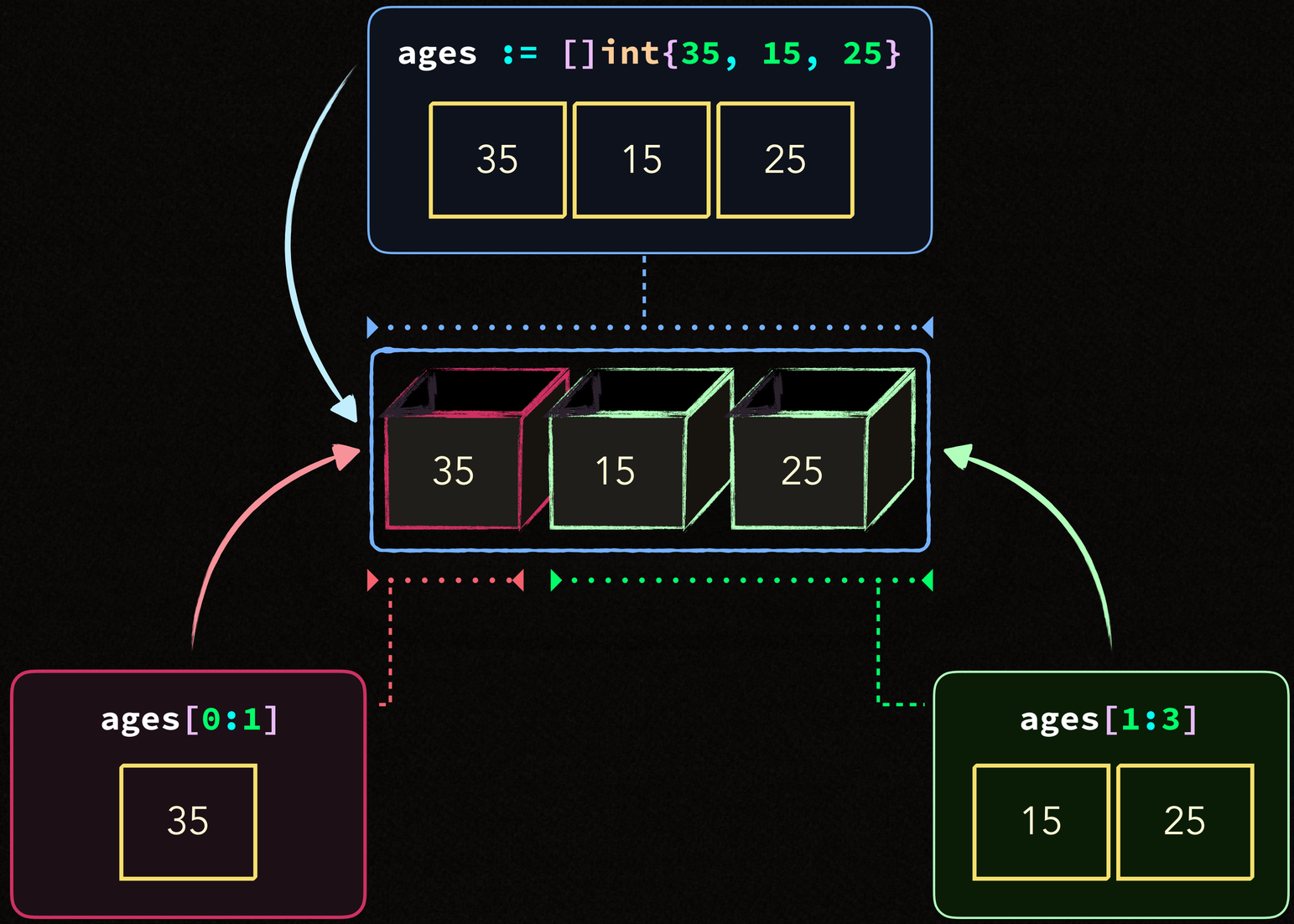
SLICE VALUE

If a slice value doesn't store any elements, so what does it contain?



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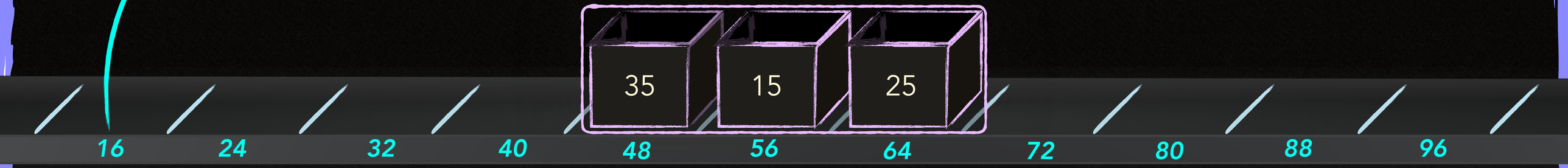
SLICE VALUE

A slice value refers to its backing array through a memory address

```
ages := []int{35, 15, 25}
```

Computer memory addresses




```
ages[0:1]
```

```
ages[1:3]
```

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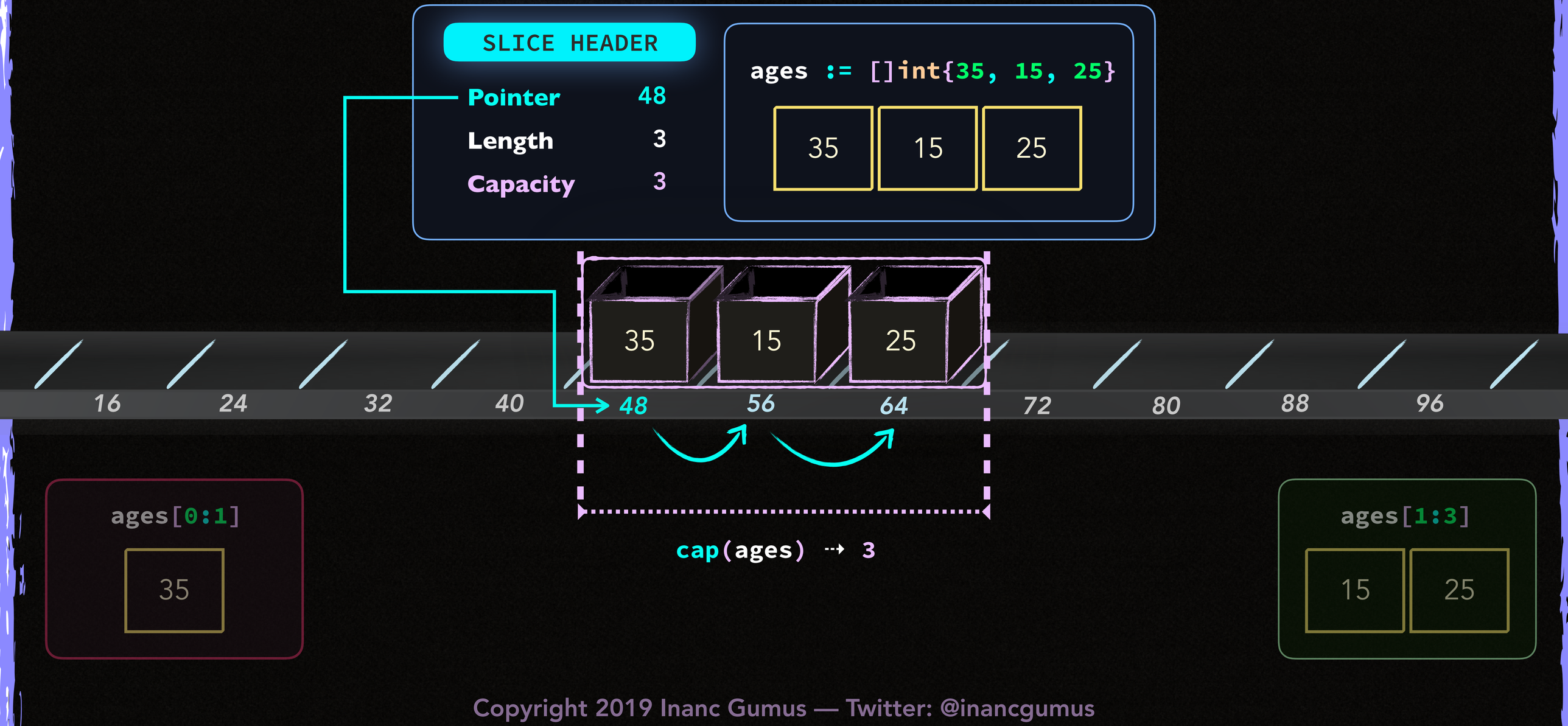
SLICE HEADER

Slice = SliceHeader, it's a tiny data structure that describes its backing array



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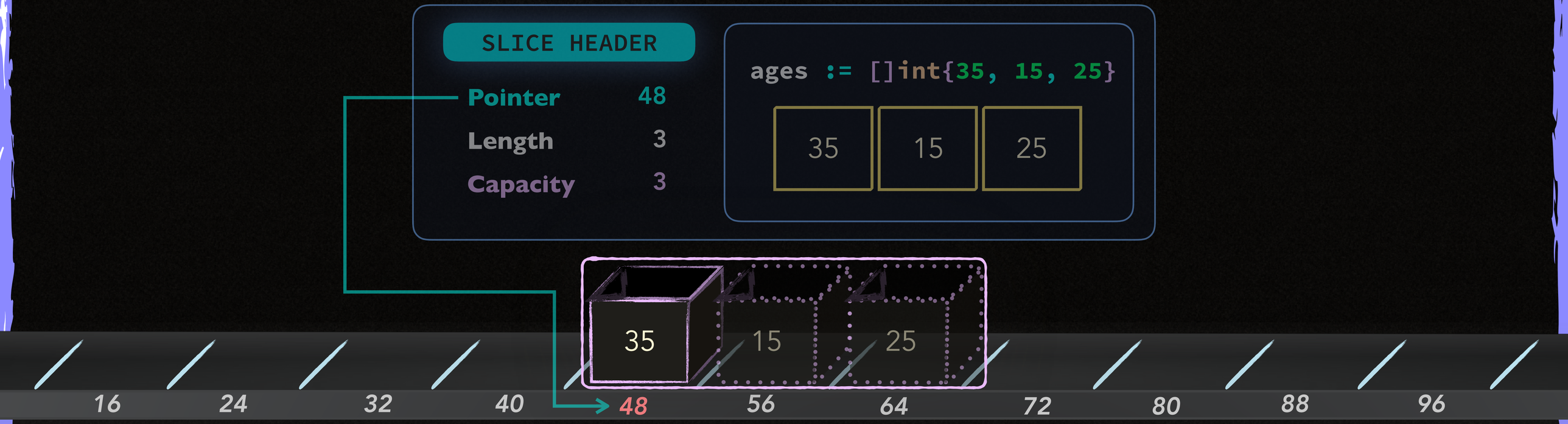
SLICE HEADER

A slice cannot index elements beyond its length *(without reslicing)*



```
red := ages[0:1]
red[0] ⇢ 35
red[1] ⇢ X
red[2] ⇢ X
```

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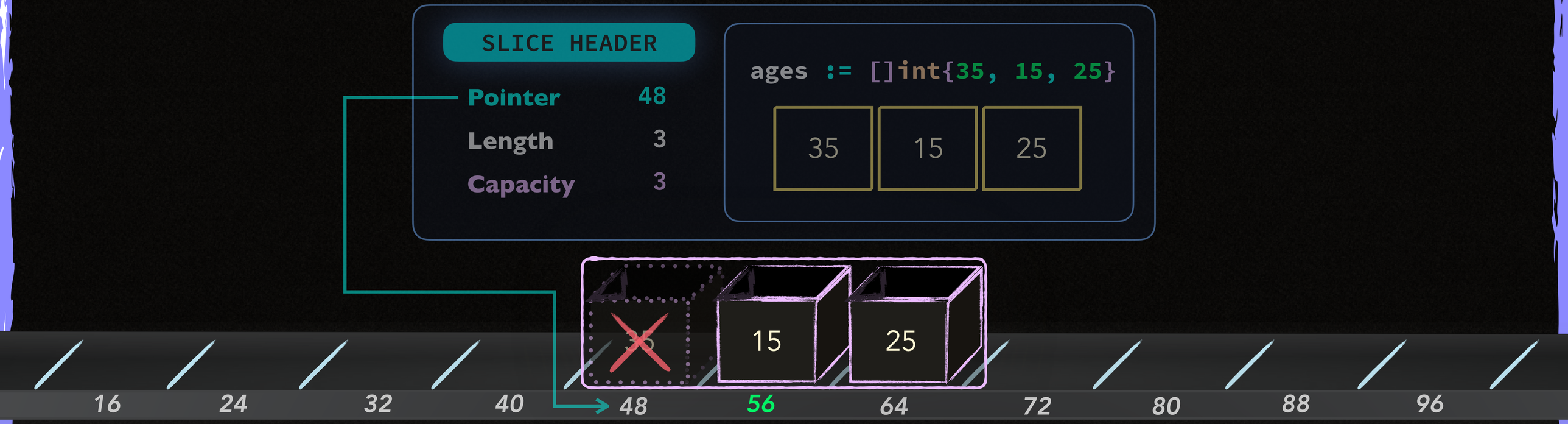
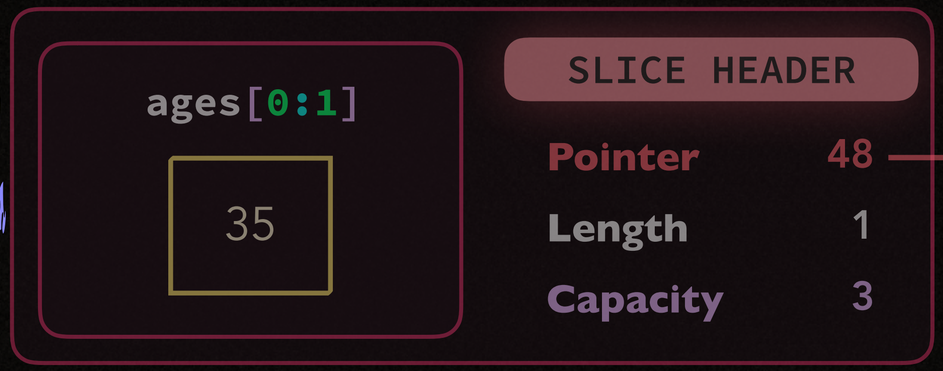
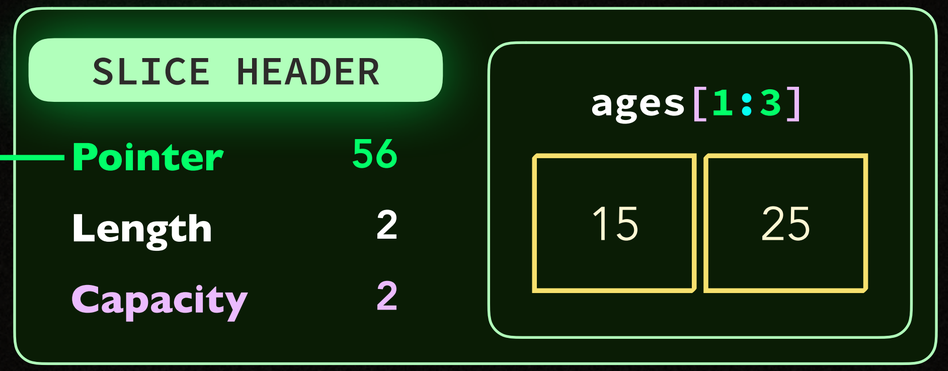
SLICE HEADER

Elements that are located before the slice's pointer remain invisible to the slice







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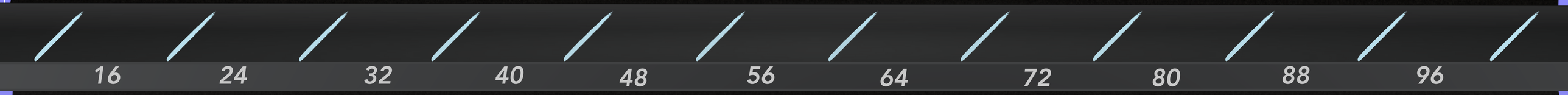
NIL SLICE

An nil slice doesn't have a backing array but it has a slice header



When you don't know whether a **slice** will ever have any elements

declare it as a nil slice

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SLICE INTERNALS

CAPACITY

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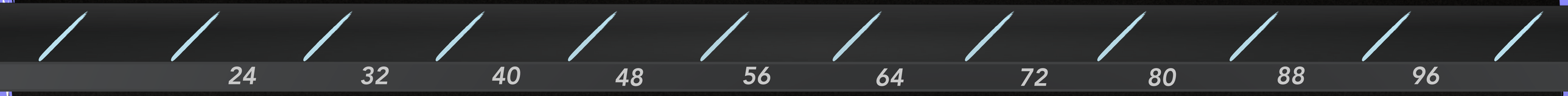
NIL SLICE

A nil slice don't have a backing array so its capacity is zero

SLICE HEADER	
Pointer	0
Length	0
Capacity	0

```
len(ages) ⇢ 0

cap(ages) ⇢ 0
```




```
var ages []int
```

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SLICE LITERAL

This slice literal has 3 elements; so it creates an array with 3 elements as well

```
ages := []int{35, 15, 25}
```

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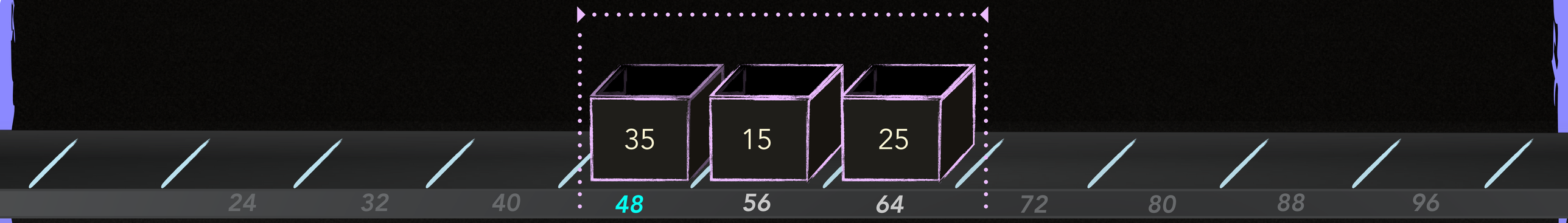
SLICE LITERAL

Capacity is the length of the backing array *(not the slice's)*

The length of this backing array is 3




```
ages := []int{35, 15, 25}
```

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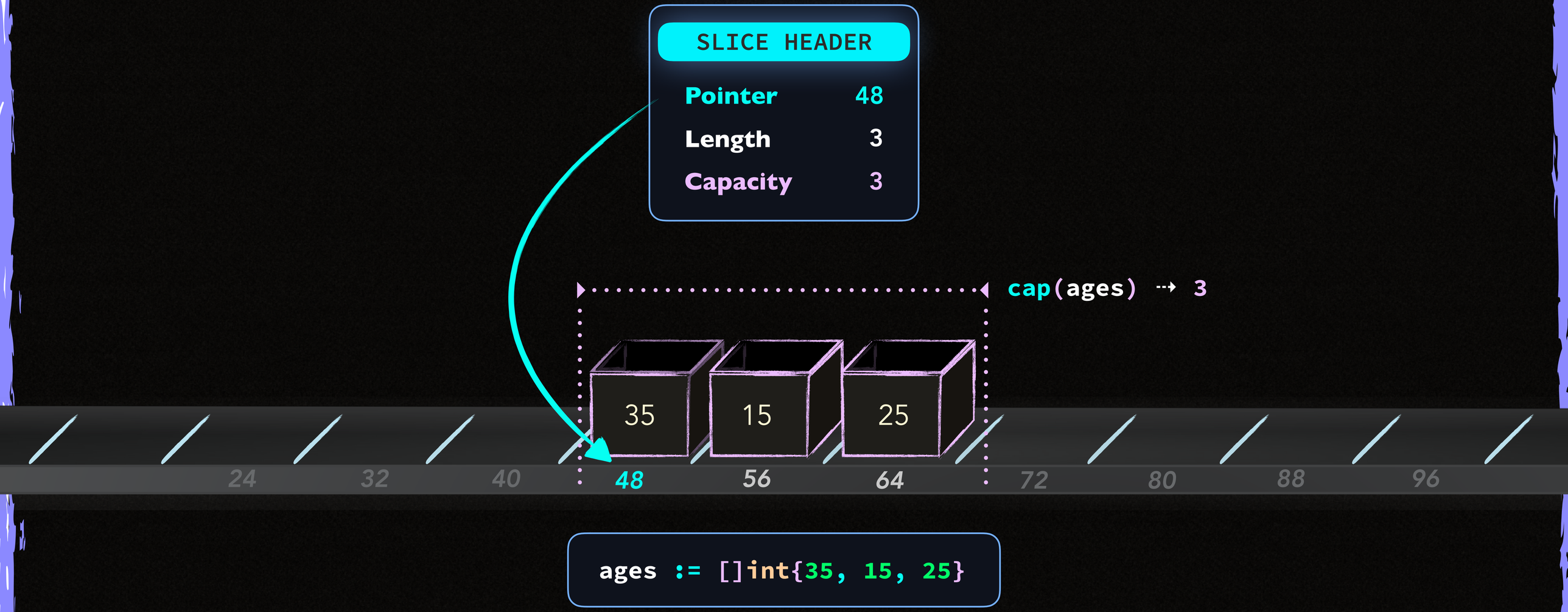
CAPACITY

Capacity is all about the length of a backing array and where a slice starts




```
ages := []int{35, 15, 25}
```

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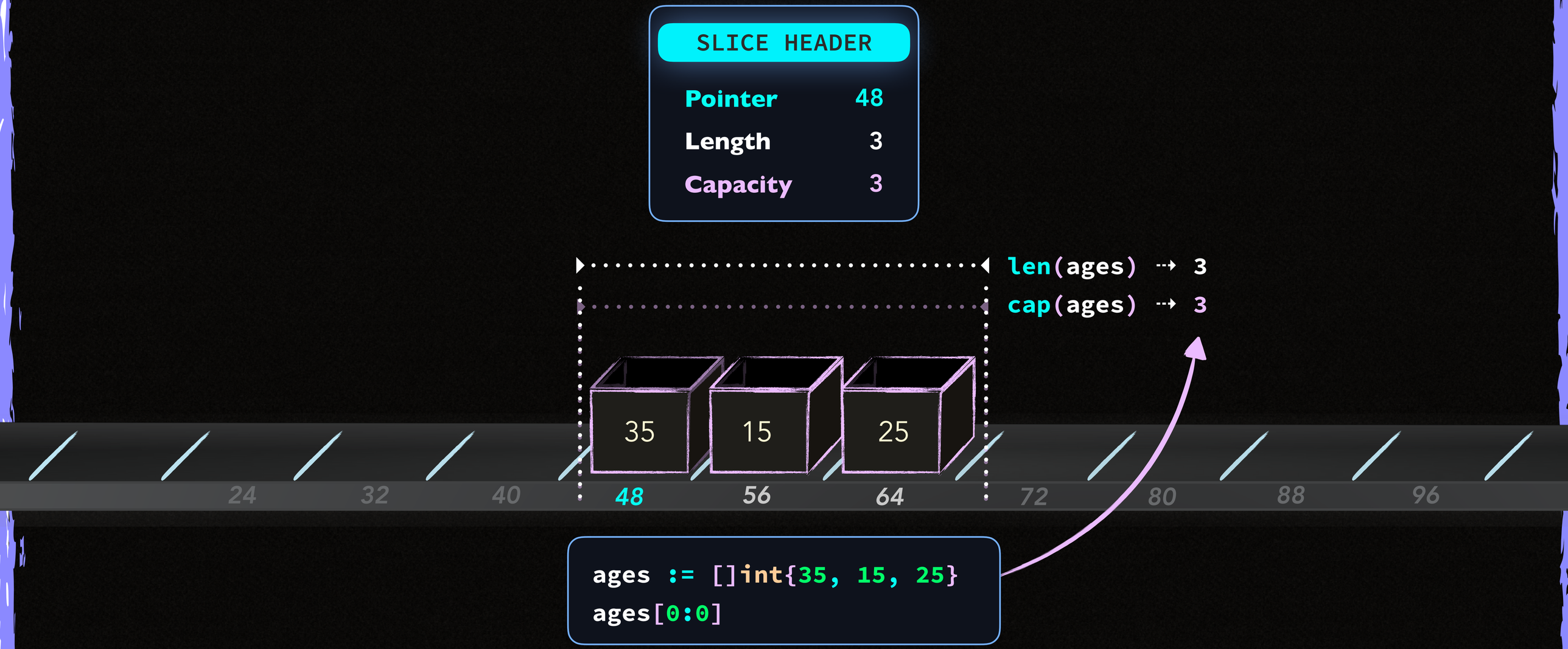
CAPACITY

A slice created by a slice literal will have the same len and cap



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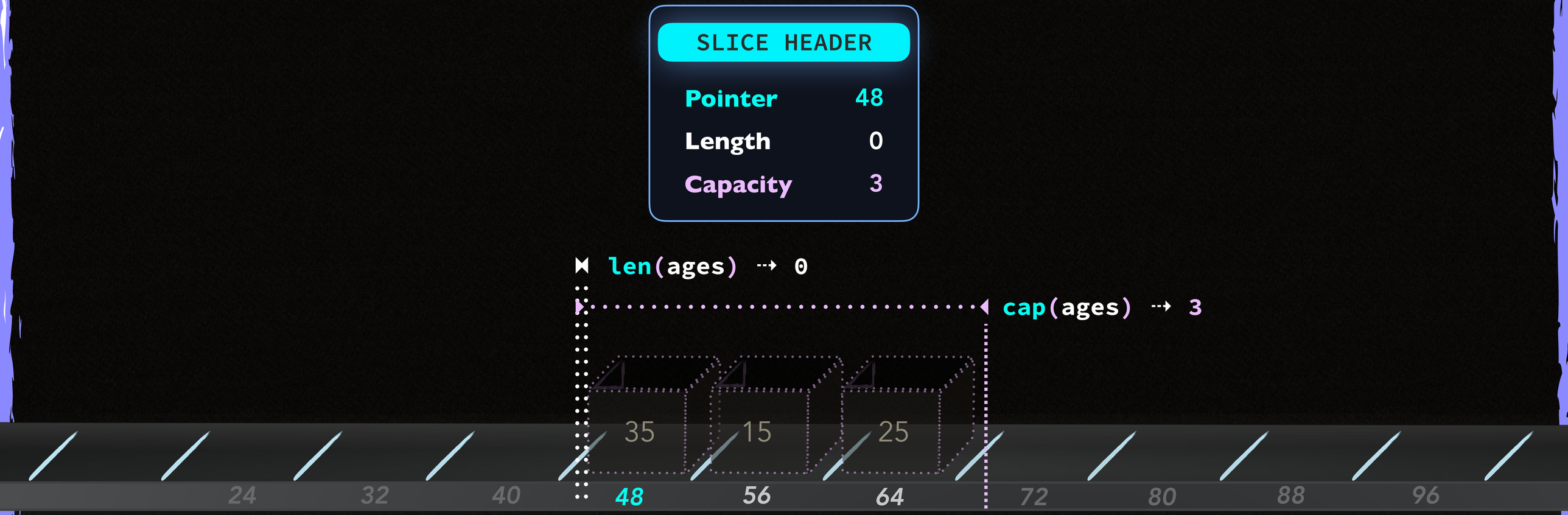
CAPACITY

This empty slice's length is zero but its backing array has 3 elements




```
ages := []int{35, 15, 25}
ages[0:0]
```

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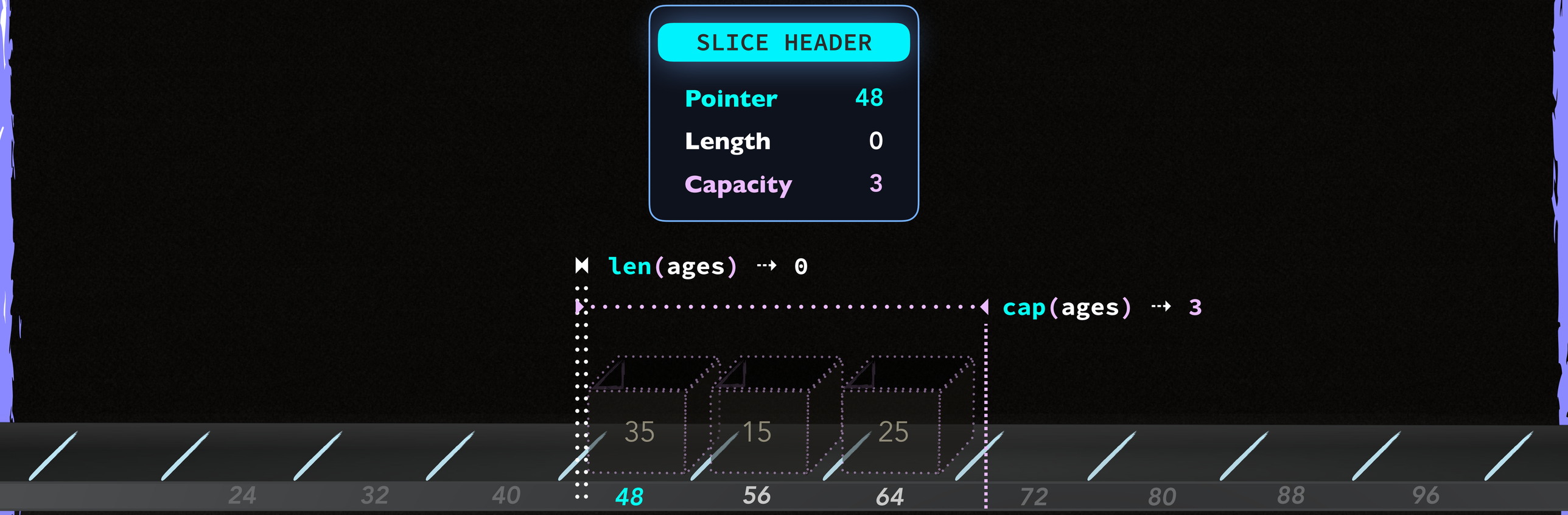
CAPACITY

Capacity determines how much you can extend a slice




```
ages := []int{35, 15, 25}
ages = ages[0:0]
ages[0:3]
```

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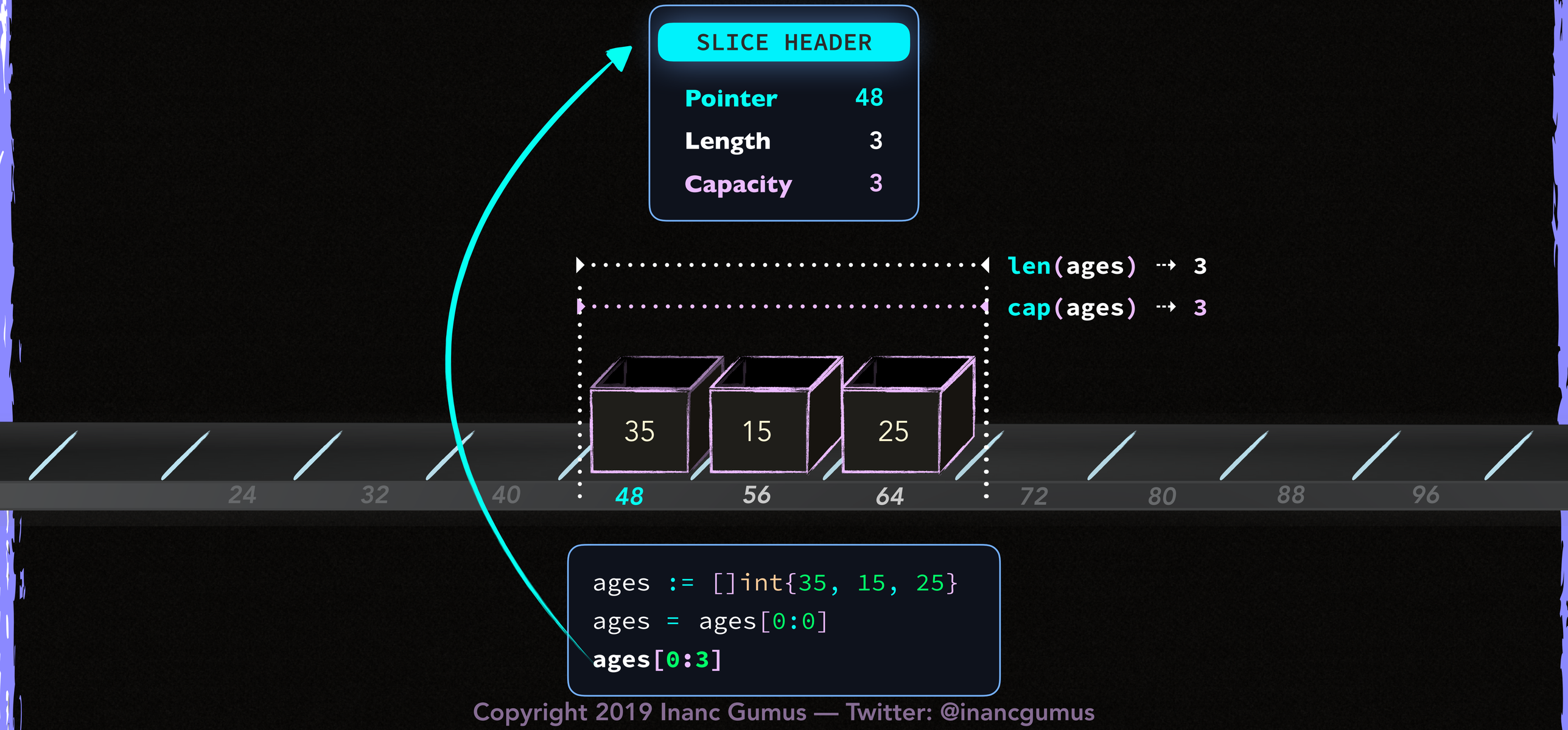
CAPACITY

Capacity determines how much you can extend a slice



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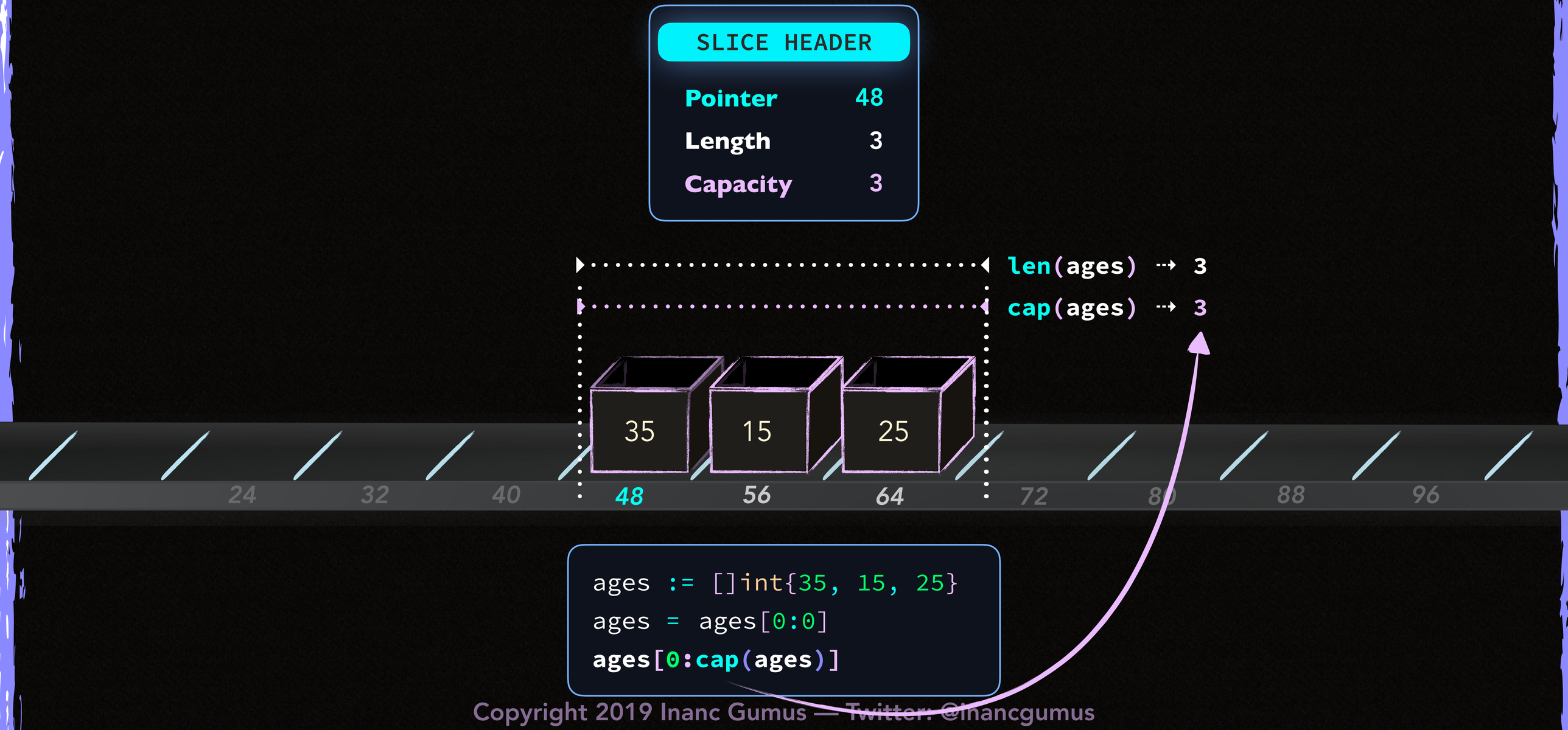
CAPACITY

cap function returns the capacity of a slice



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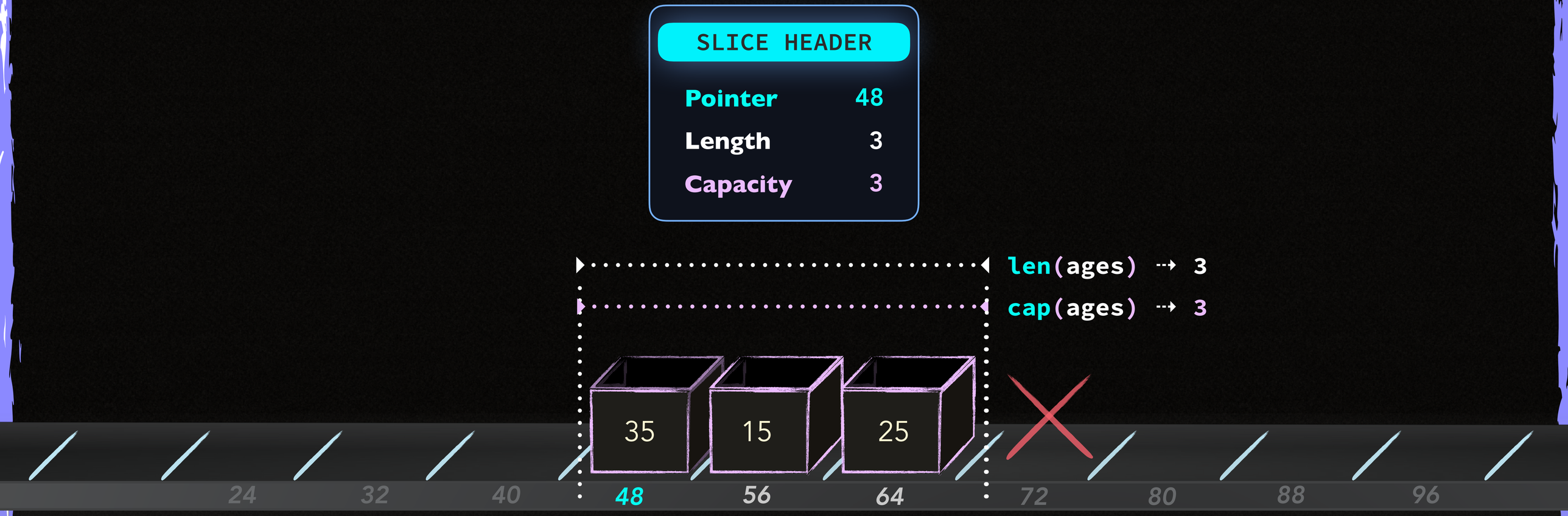
CAPACITY

You cannot extend a slice beyond its capacity




```
ages := []int{35, 15, 25}
ages = ages[0:0]
ages[0:cap(ages) + 1]
```

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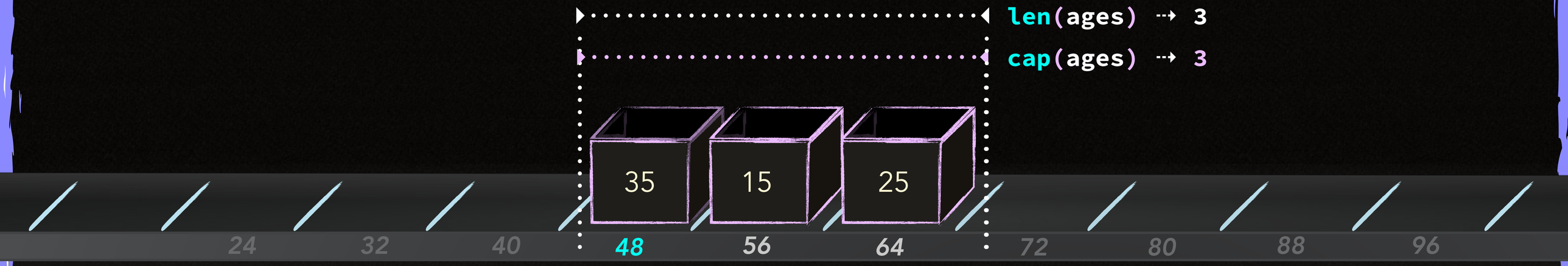
CAPACITY

Capacity is the length of the backing array after the slice's first item

SLICE HEADER	
Pointer	48
Length	3
Capacity	3




```
ages := []int{35, 15, 25}
ages[1:3]
```

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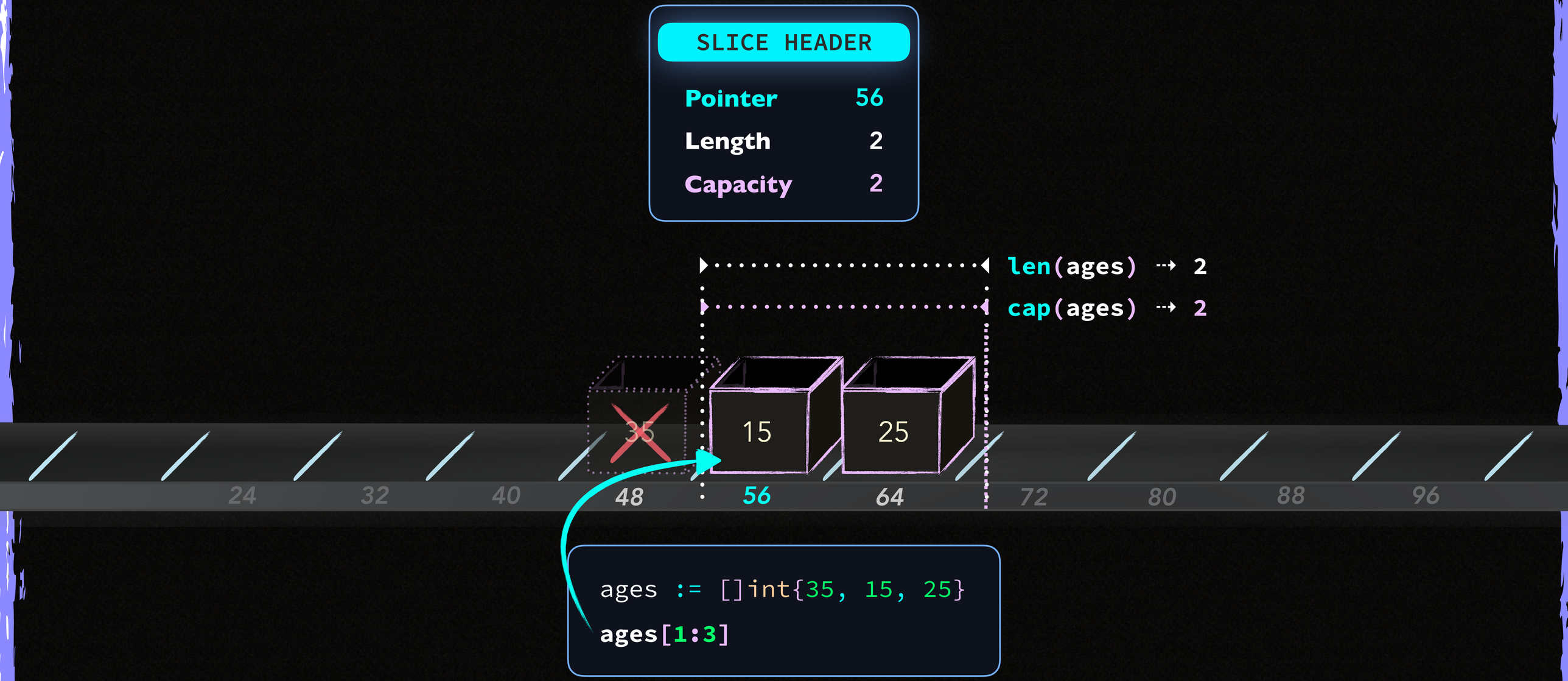
CAPACITY

Capacity is the length of the backing array after the slice's first item



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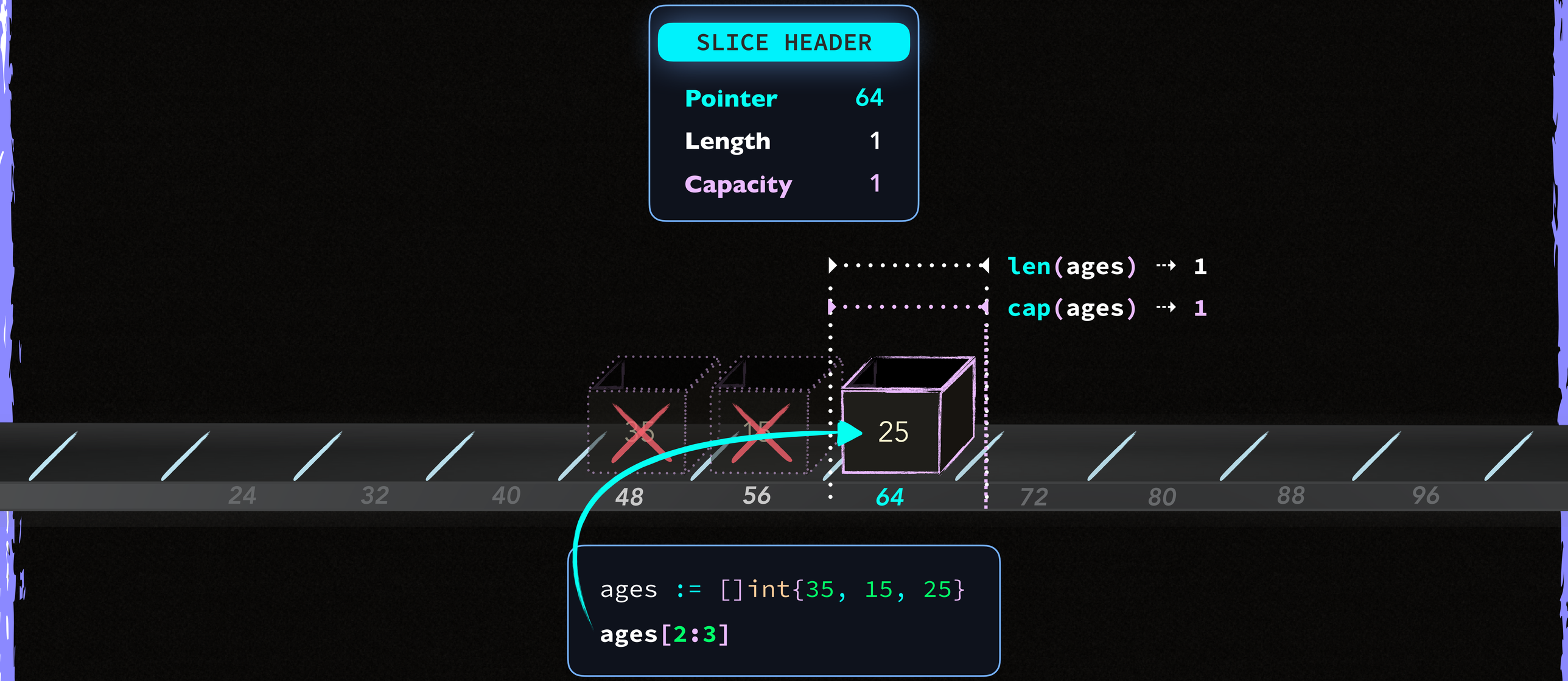
CAPACITY

Capacity is the length of the backing array after the slice's first item



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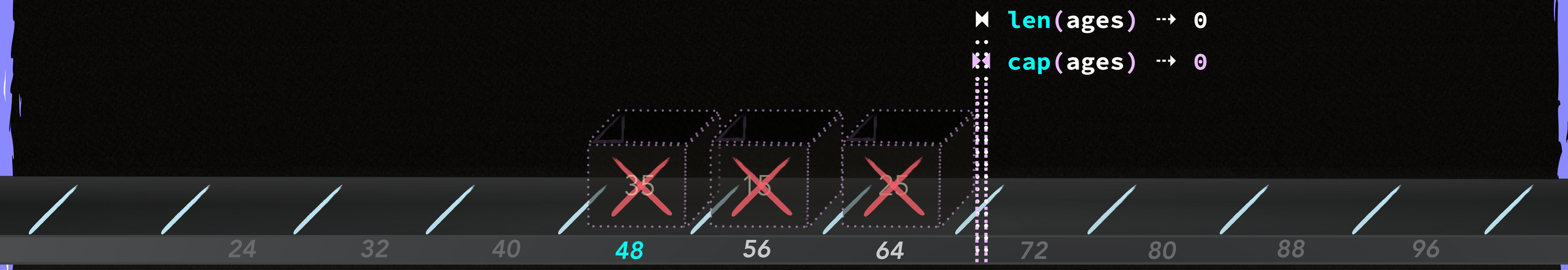
CAPACITY

An empty slice's length is zero but it has a backing array

SLICE HEADER	
Pointer	48
Length	0
Capacity	0




```
ages := []int{35, 15, 25}
ages[3:3]
```

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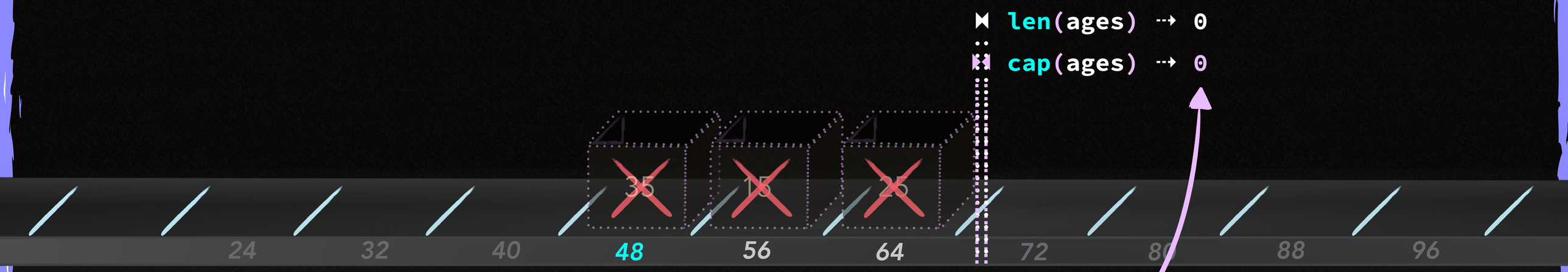
CAPACITY

You cannot extend back when you lost the original slice header

SLICE HEADER	
Pointer	48
Length	0
Capacity	0




```
ages := []int{35, 15, 25}
ages := ages[3:3]
ages[0:3]
```

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SLICE INTERNALS

THE MECHANICS OF APPEND

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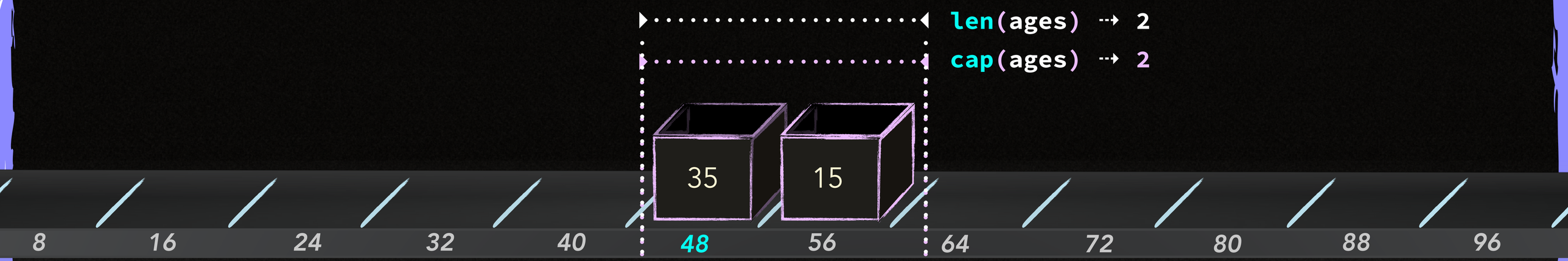
MECHANICS OF APPEND

What would happen if you append one more element to this slice?

```
ages := []int{35, 15}
```



SLICE HEADER	
Pointer	48
Length	2
Capacity	2

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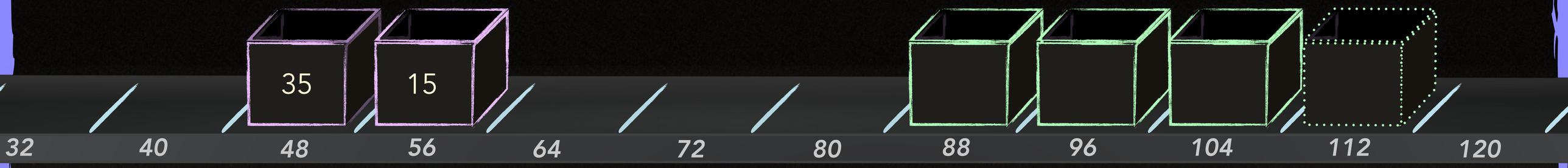
MECHANICS OF APPEND

When the capacity is full; append() allocates a new and a larger array

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```



SLICE HEADER	
Pointer	48
Length	2
Capacity	2

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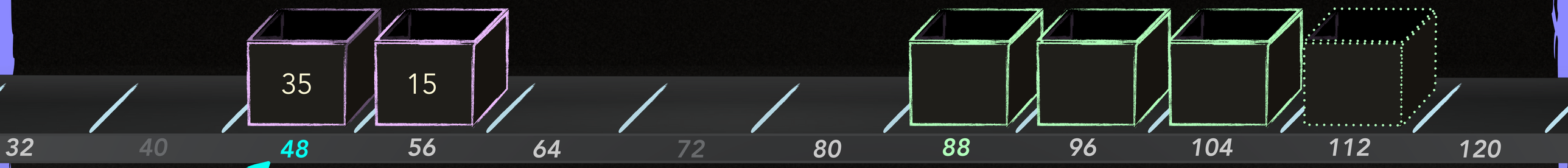
MECHANICS OF APPEND

Returns a new slice header that points to the newly allocated array

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```



SLICE HEADER	
Pointer	48
Length	2
Capacity	2

SLICE HEADER	
Pointer	88
Length	3
Capacity	4

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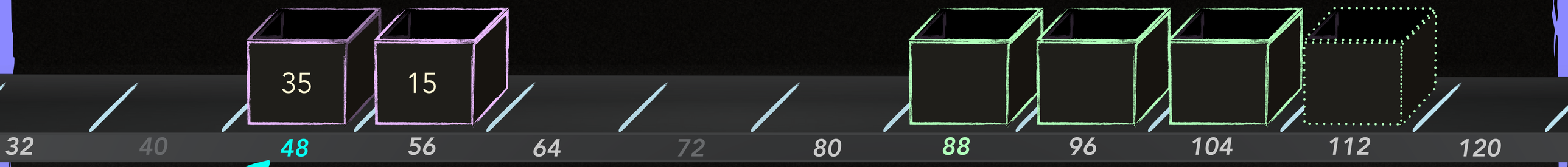
MECHANICS OF APPEND

Why append() allocates a larger array?

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```



SLICE HEADER	
Pointer	48
Length	2
Capacity	2

SLICE HEADER	
Pointer	88
Length	3
Capacity	4

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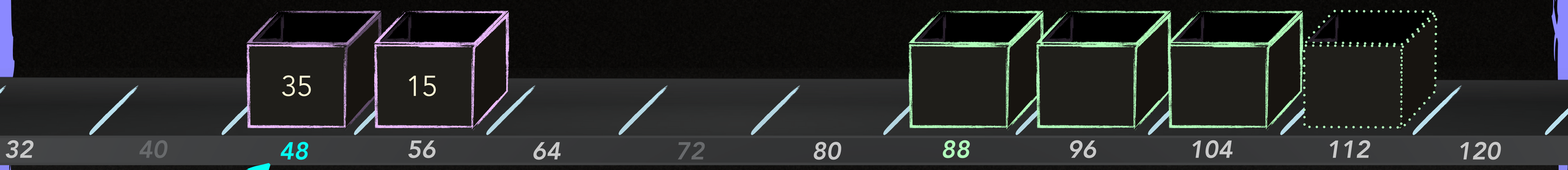
MECHANICS OF APPEND

Allocating a larger array reduces the number of allocations in the future

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```



SLICE HEADER	
Pointer	48
Length	2
Capacity	2

SLICE HEADER	
Pointer	88
Length	3
Capacity	4

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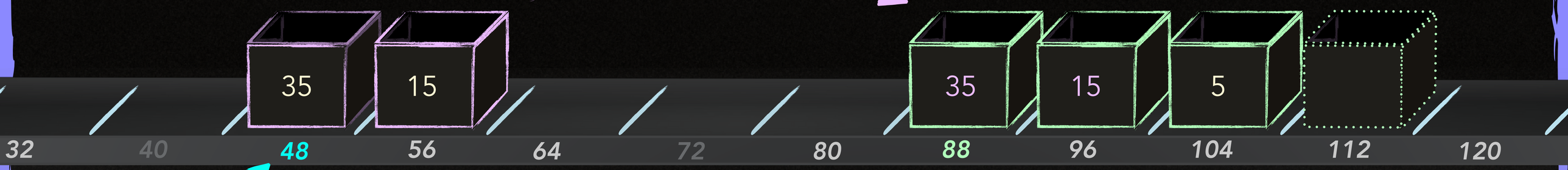
MECHANICS OF APPEND

Copies the elements of the previous array to the new array

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```



SLICE HEADER	
Pointer	48
Length	2
Capacity	2

SLICE HEADER	
Pointer	88
Length	3
Capacity	4

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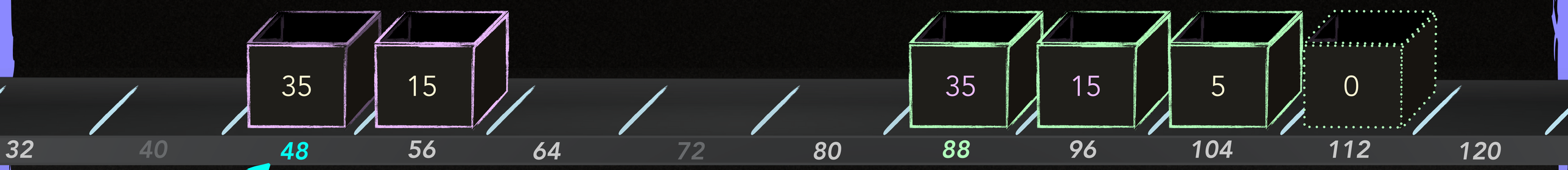
MECHANICS OF APPEND

Assigns zero values to uninitialized elements of the backing array

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```



SLICE HEADER	
Pointer	48
Length	2
Capacity	2

SLICE HEADER	
Pointer	88
Length	3
Capacity	4

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FULL SLICE EXPRESSIONS

Sometimes you need to " limit " yourself

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```
newSlice := slicable[START:STOP]
```

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```
newSlice := slicable[START:STOP:CAP]
```

"CAP" limits the returned slice's capacity

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```
sliceable := []byte{'f', 'u', 'l', 'l'}
```

sliceable[0:3] 0 1 2 3 4

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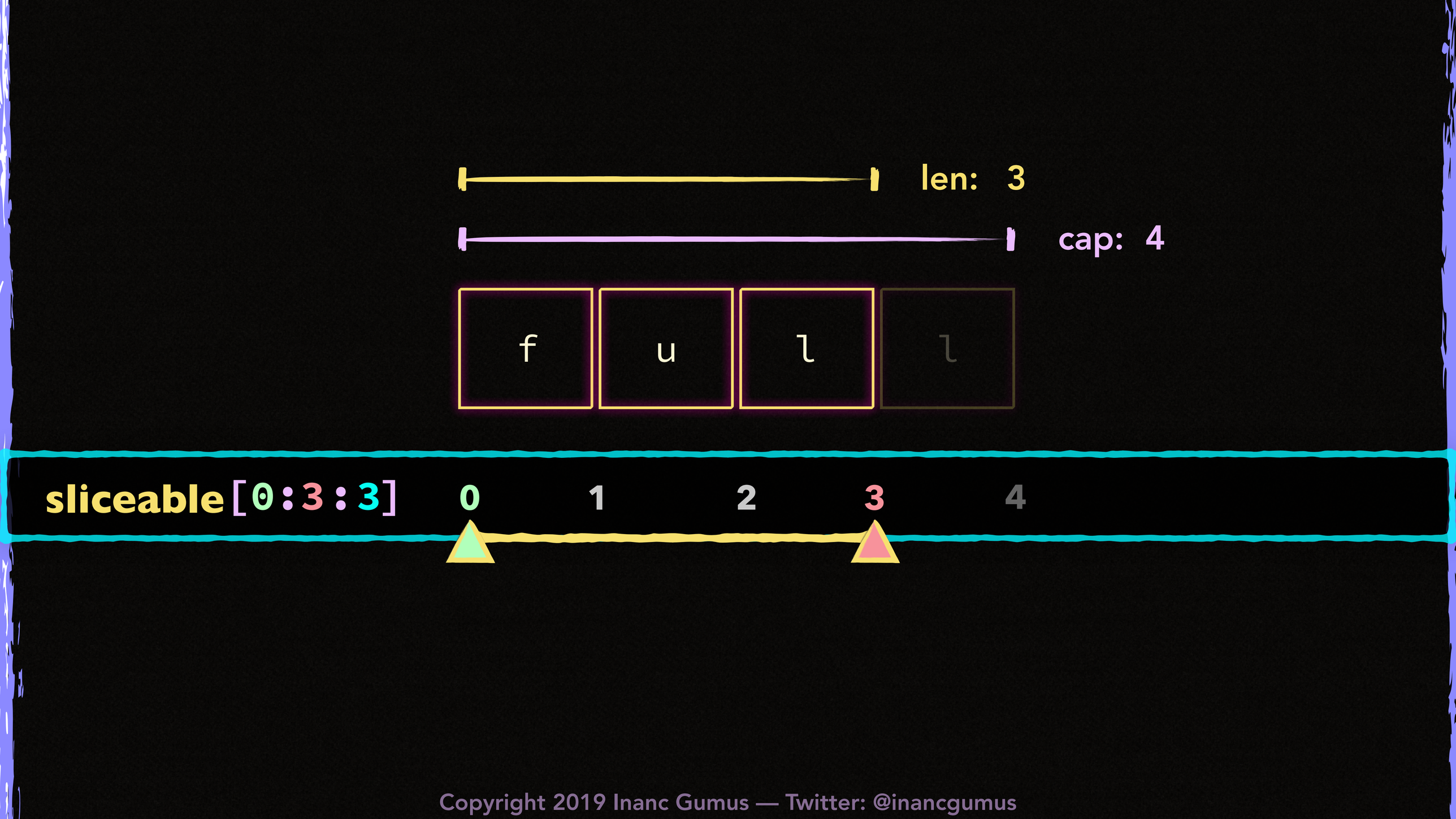

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think of the **capacity position** as
the element position in **the backing array**

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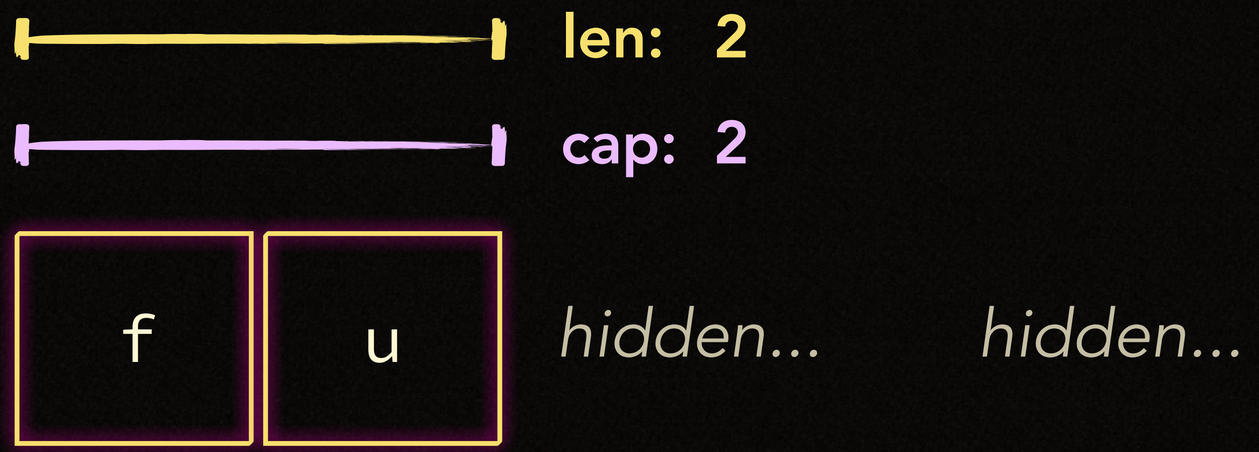

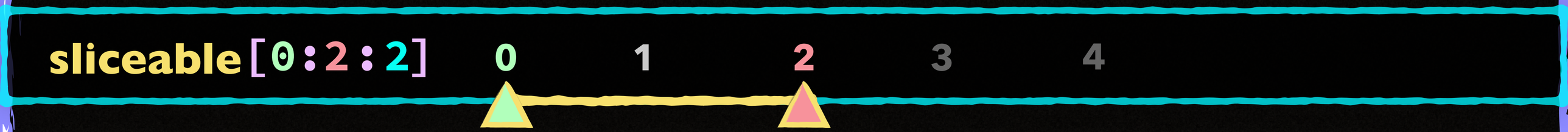

stop position <= capacity position

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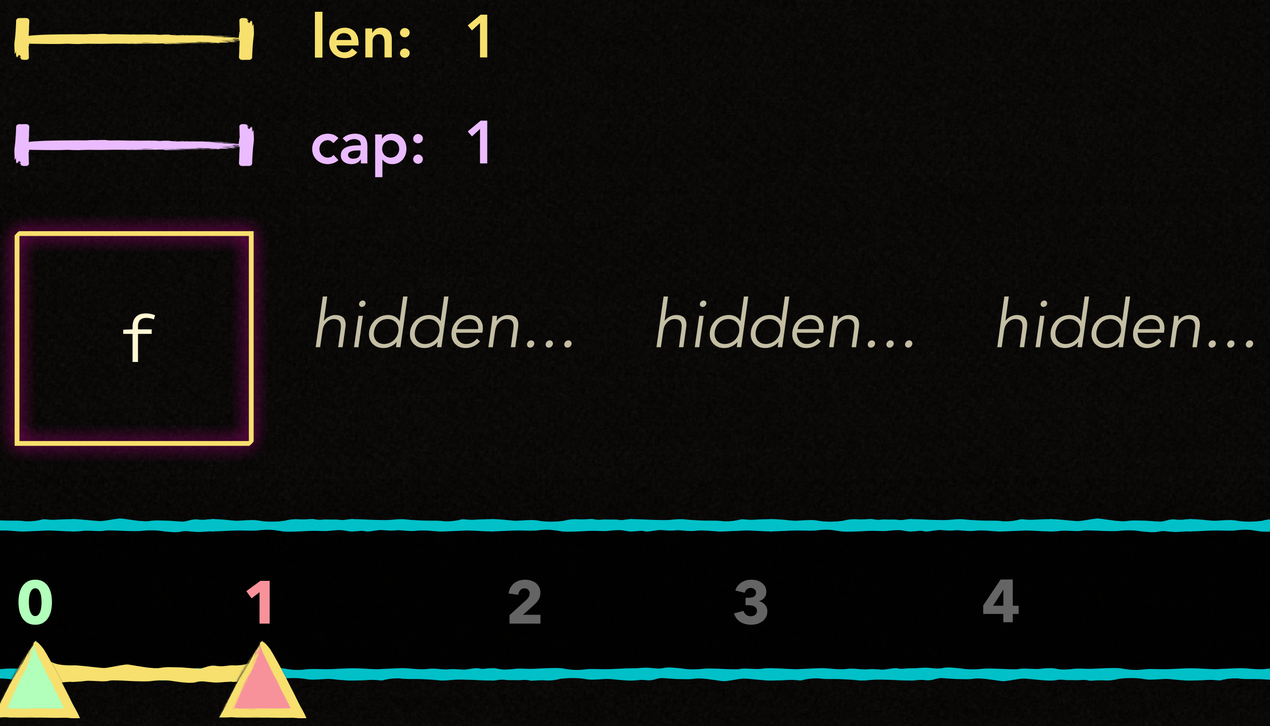

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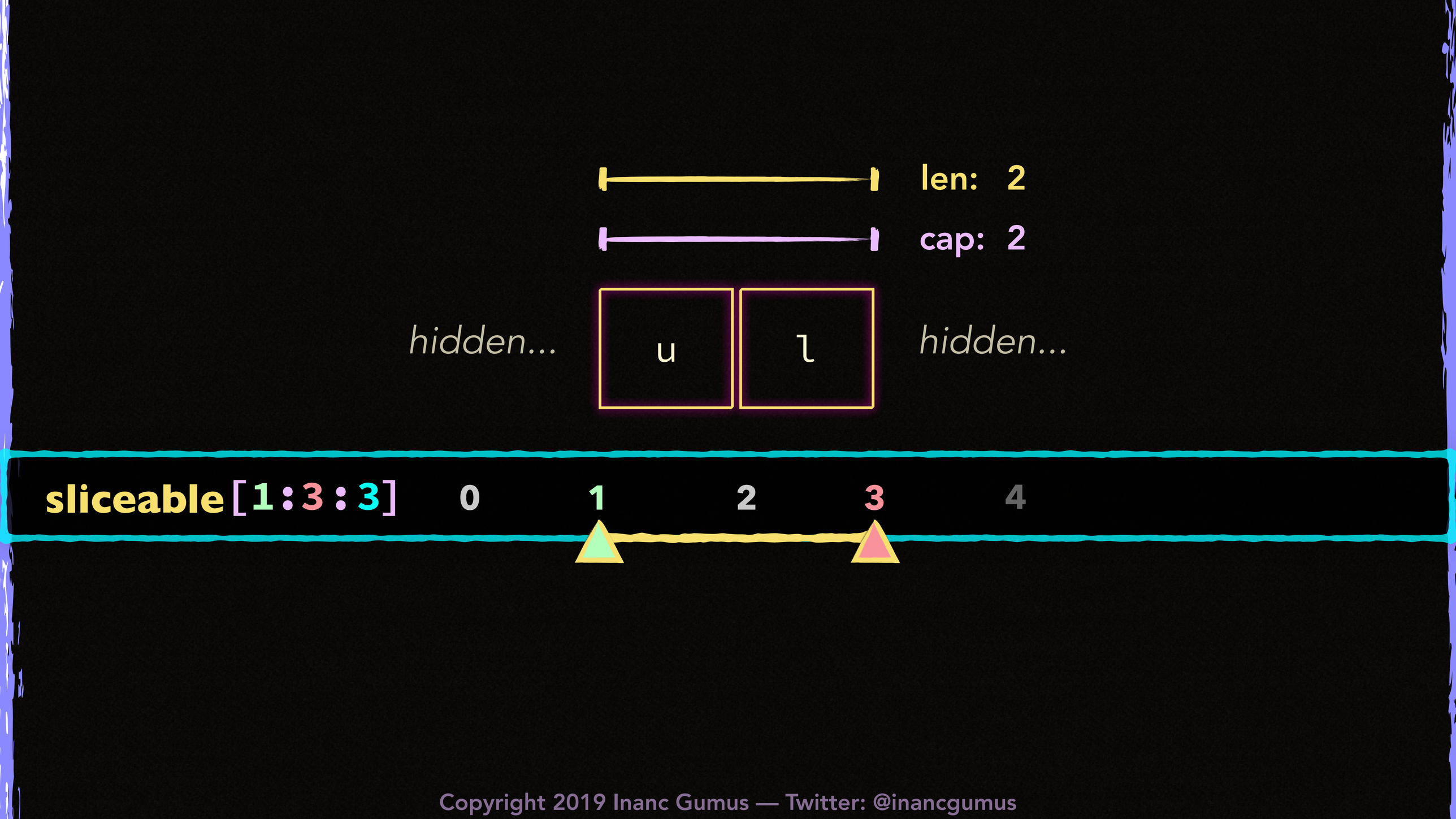

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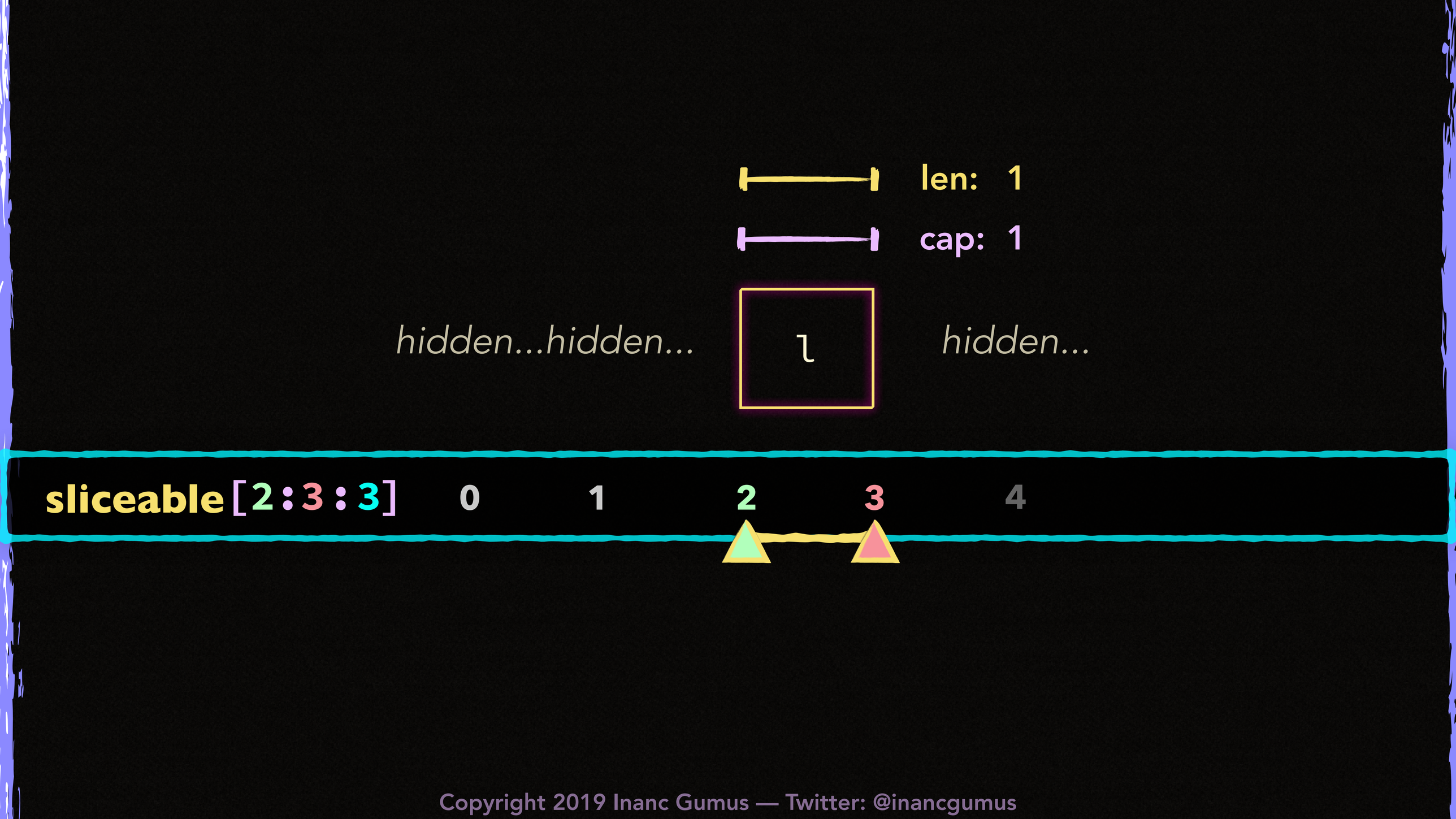

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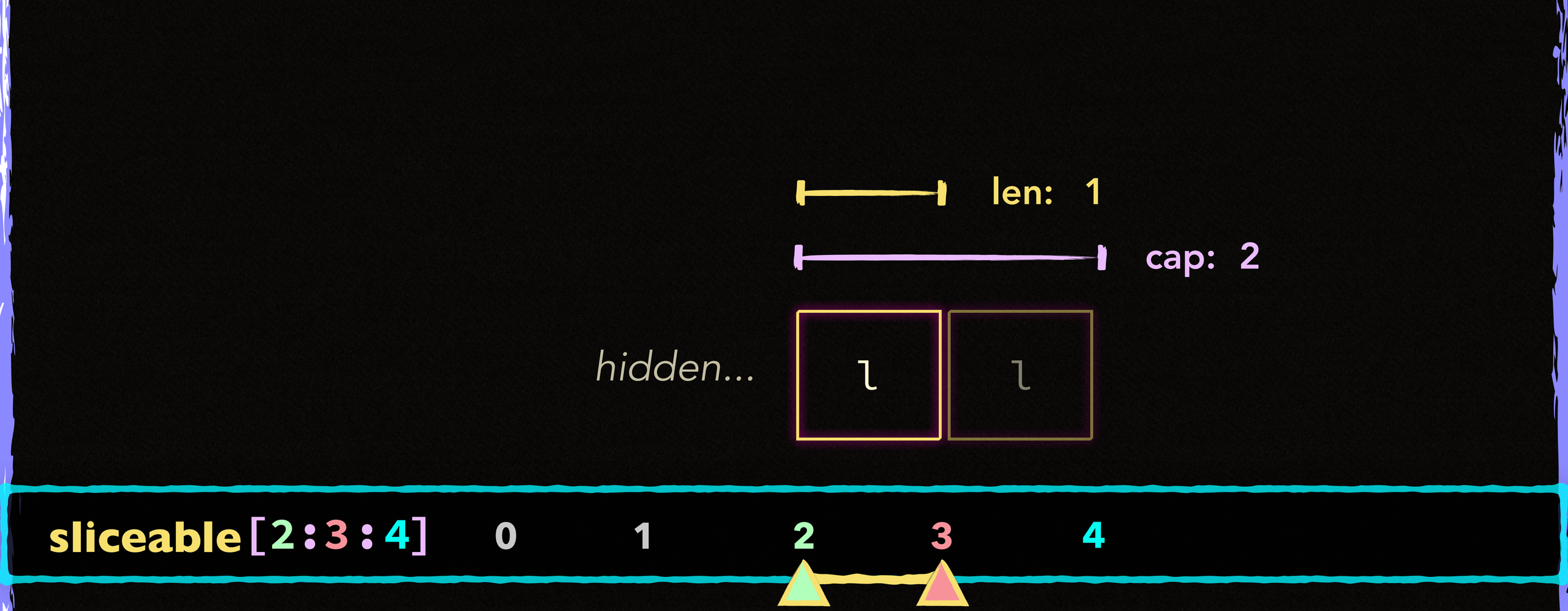

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len: 0

cap: 0

hidden... *hidden...* *hidden...* *hidden...*

sliceable[4:4:4] 0 1 2 3 4

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MAKE

Preallocate Backing Arrays

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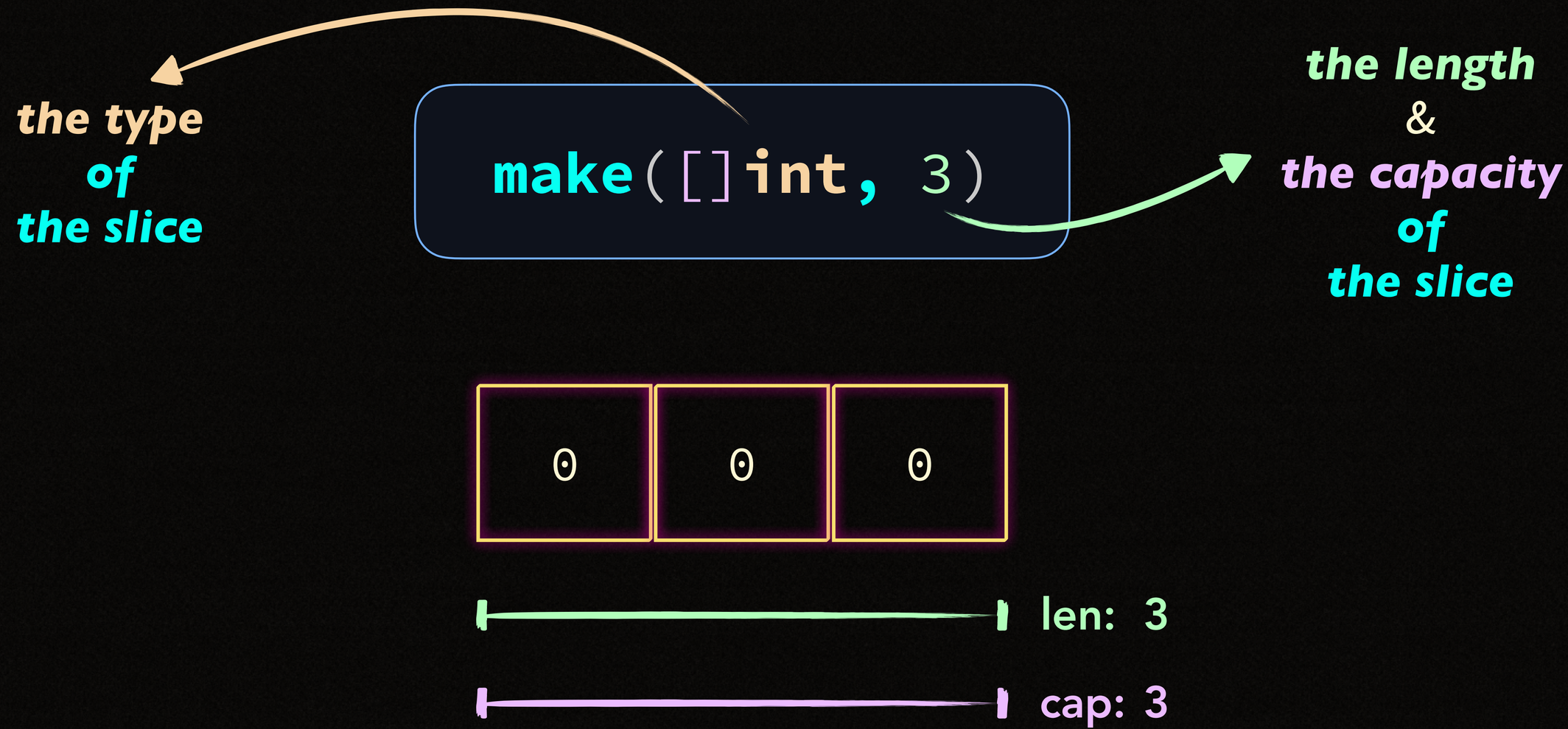
MAKE

make initializes and returns a slice with the given length and capacity



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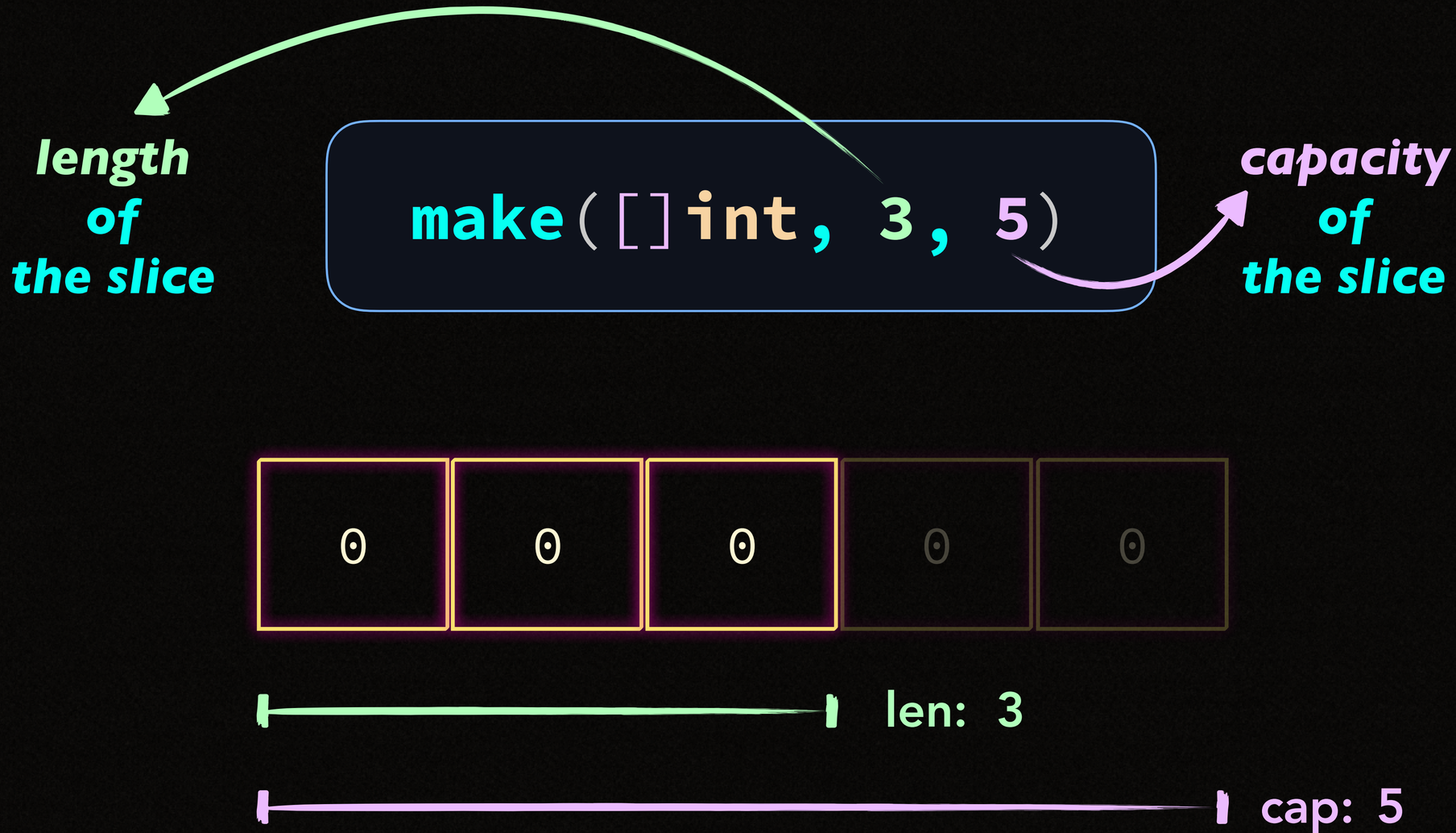
MAKE

make initializes and returns a slice with the given length and capacity



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MAKE

when the given length is 0, the make() will return a slice, ready to append

```
make([]int, 0, 5)
```

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MAKE

when the given length is 0, the make() will return a slice, ready to append

ready to append

```
s := make([]int, 0, 5)
s  = append(s, 42)
```

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MAKE

when the given length is 0, the make() will return a slice, ready to append

```
s := make([]int, 0, 5)
s  = append(s, 42)
```

ready to append

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COPY

Copies the elements of a slice to another slice

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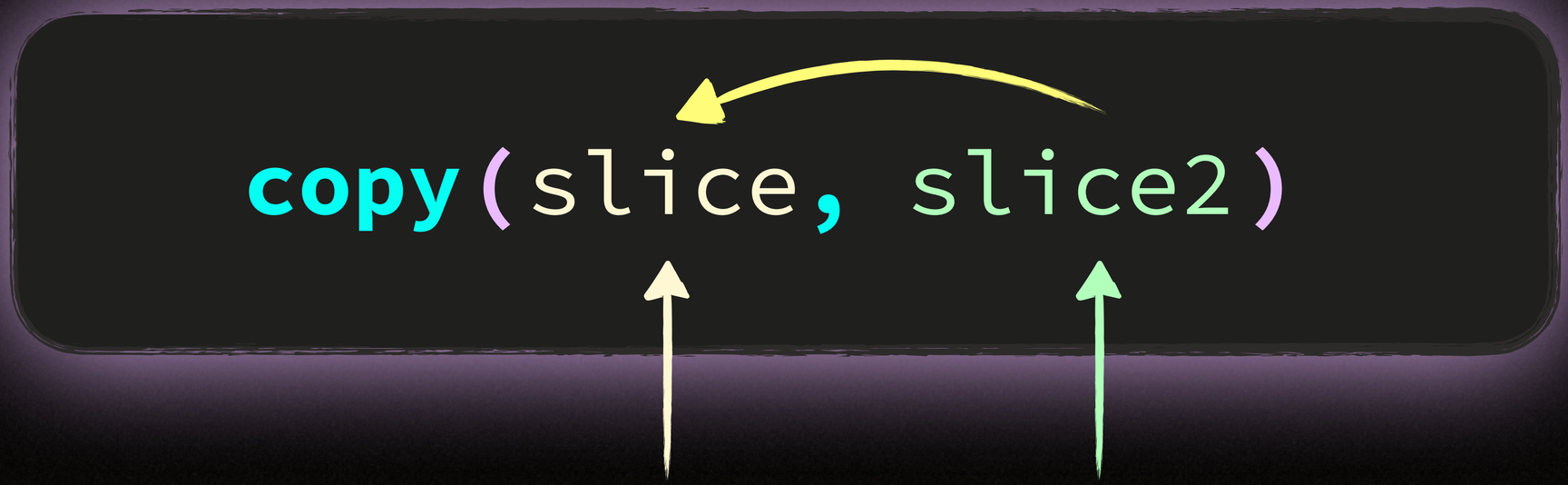
COPY

Copies the elements of a slice to another slice



the element types of the slices should be identical

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COPY

Copies the elements of a slice to another slice

```
evens := []int{2, 4}
```

```
odds := []int{3, 5, 7}
```

```
copy(evens, odds)
```

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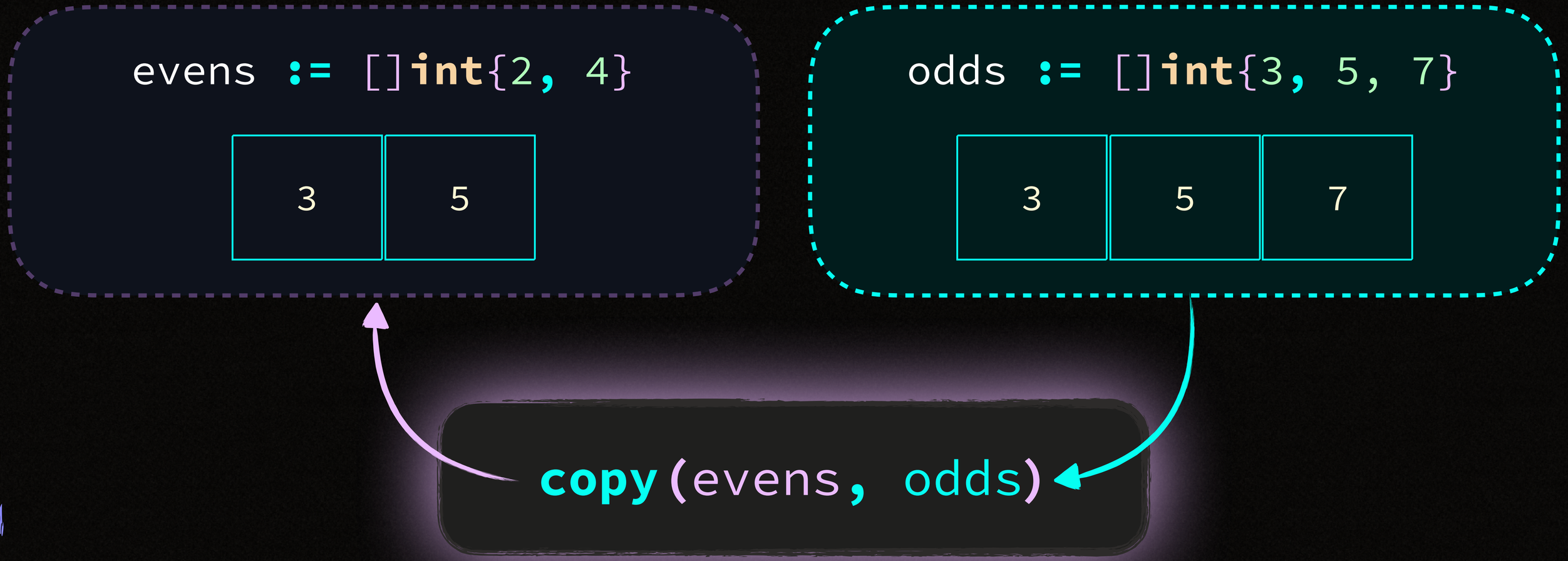
COPY

Copies the elements *based on* the length of the smallest slice



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COPY

It returns the number of copied elements

```
evens := []int{2, 4}
```

```
odds := []int{3, 5, 7}
```

```
N := copy(evens, odds)
```

2 elements are copied

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summary

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SLICES vs ARRAYS

Slices are dynamic — Arrays are fixed

SLICE

```
var nums []int
```

Its length is *not* part of its type

It can grow and shrink

Its zero value is nil

ARRAY

```
var nums [2]int
```

Its length is part of its type

It cannot grow or shrink

Its zero value is zero valued elements

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You can only compare a slice value to a nil value

```
var nums []int    ==    nil
```

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nil slice

```
var nums []int
```

empty slice

```
nums := []int{}
```

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APPEND

Appends an element to a slice and returns a new slice

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APPEND

It appends the elements after the length of the given slice

```
nums := []int{1, 2, 3}
nums = append(nums, 4, 9)
```

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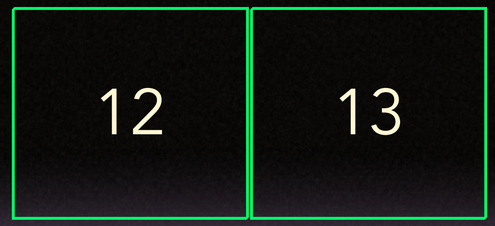
APPEND

Ellipsis allows you to append a slice to another slice




```
nums := []int{1, 2, 3}
tens := []int{12, 13}
nums = append(nums, tens...)
```

```
append(nums, 12, 13)
```

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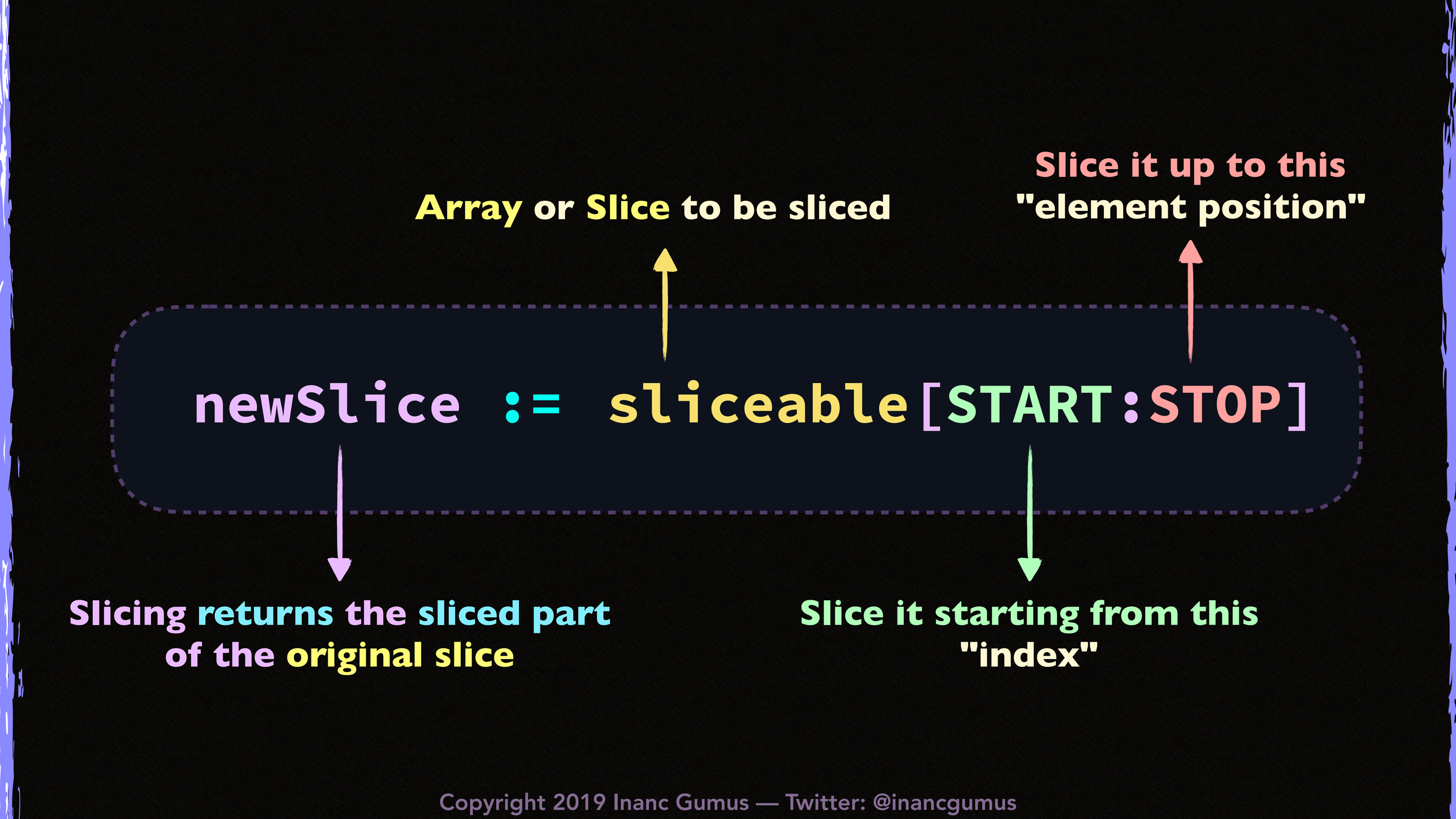

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SLICE EXPRESSIONS

Creates a new slice from 1st index to the 4th element

```
msg := []byte{'h', 'e', 'l', 'l', 'o'}
```

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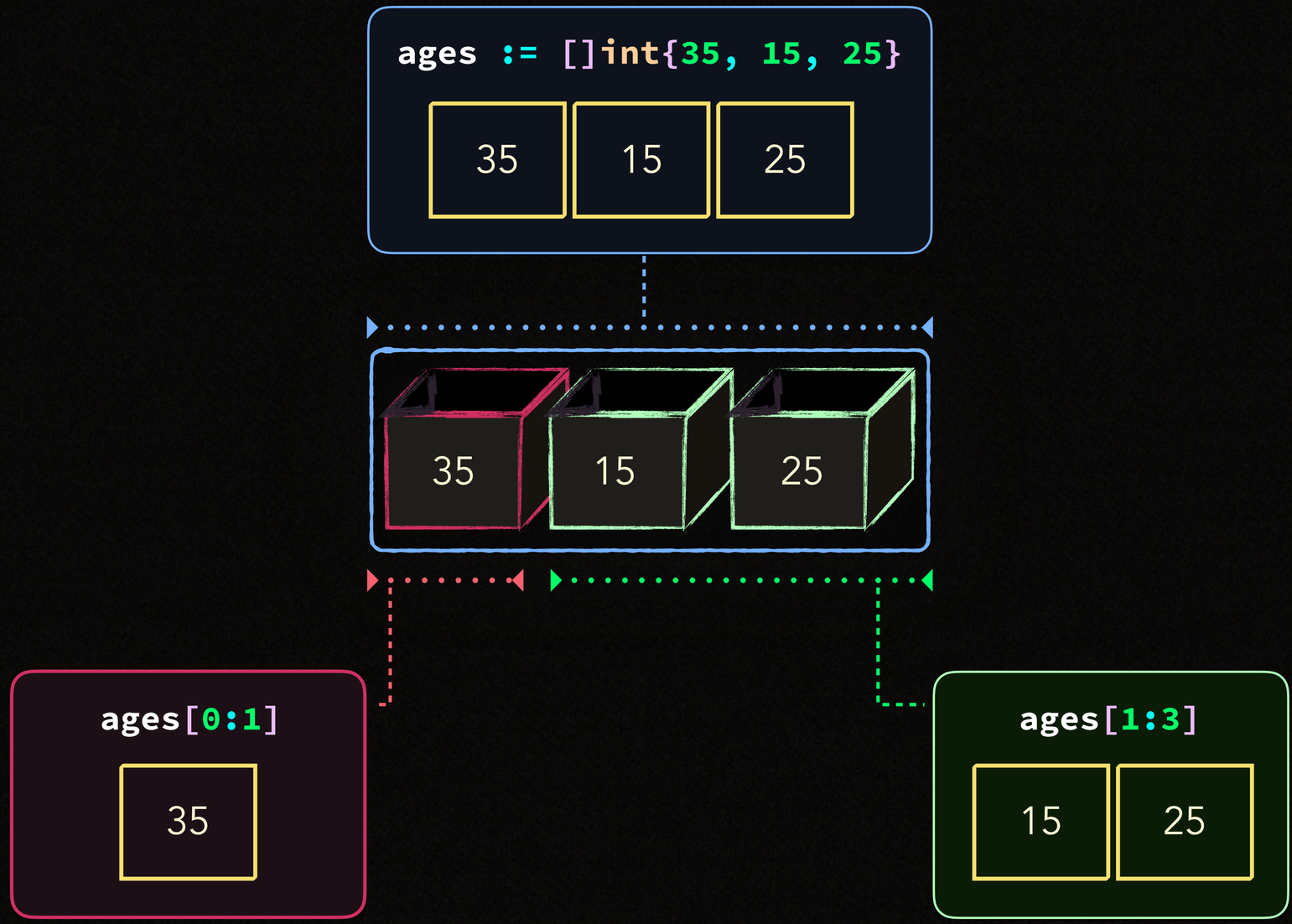
BACKING ARRAY

A slice is a window to its backing array



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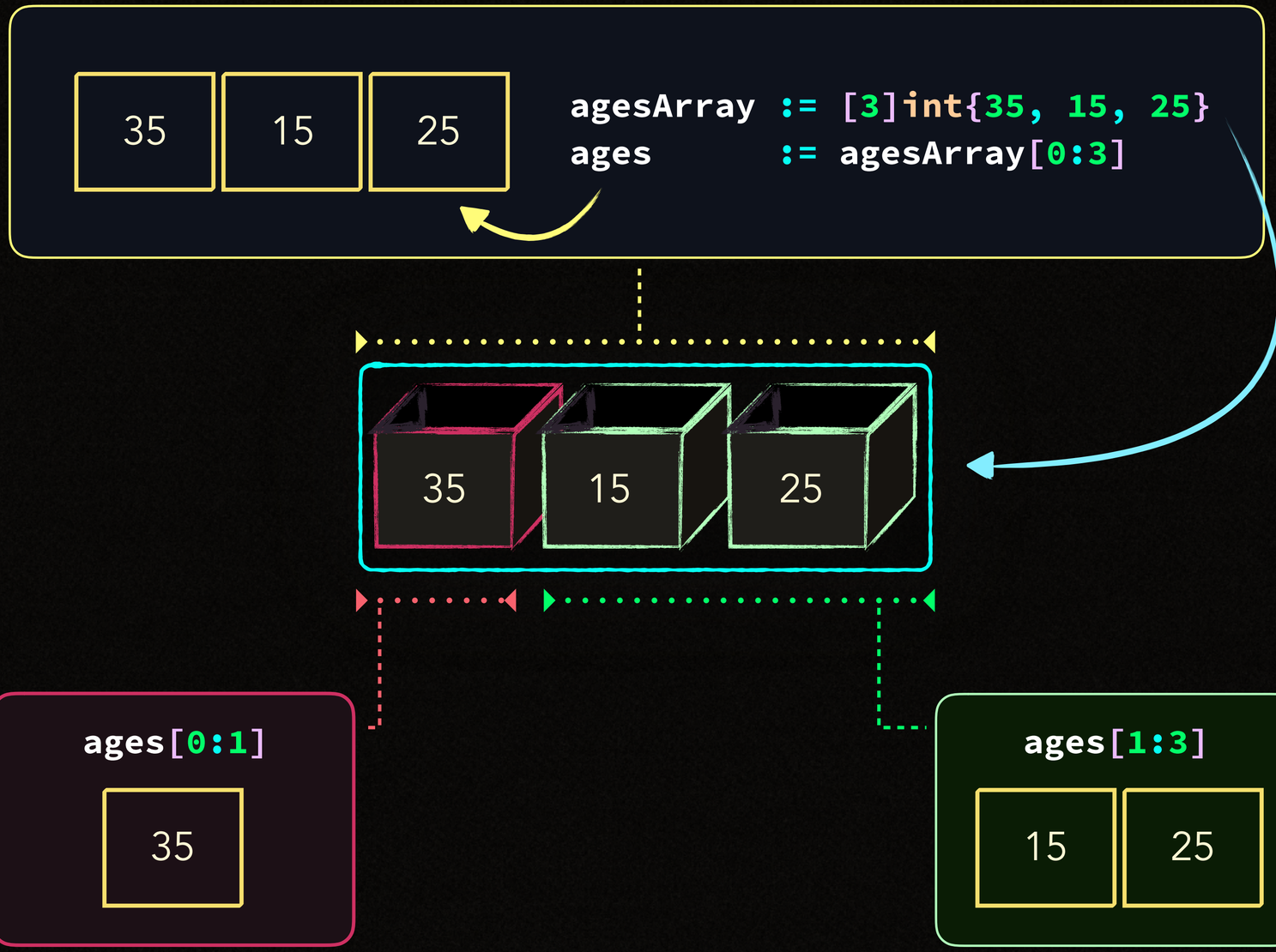
BACKING ARRAY

A sliced array becomes the backing array of the returned slice



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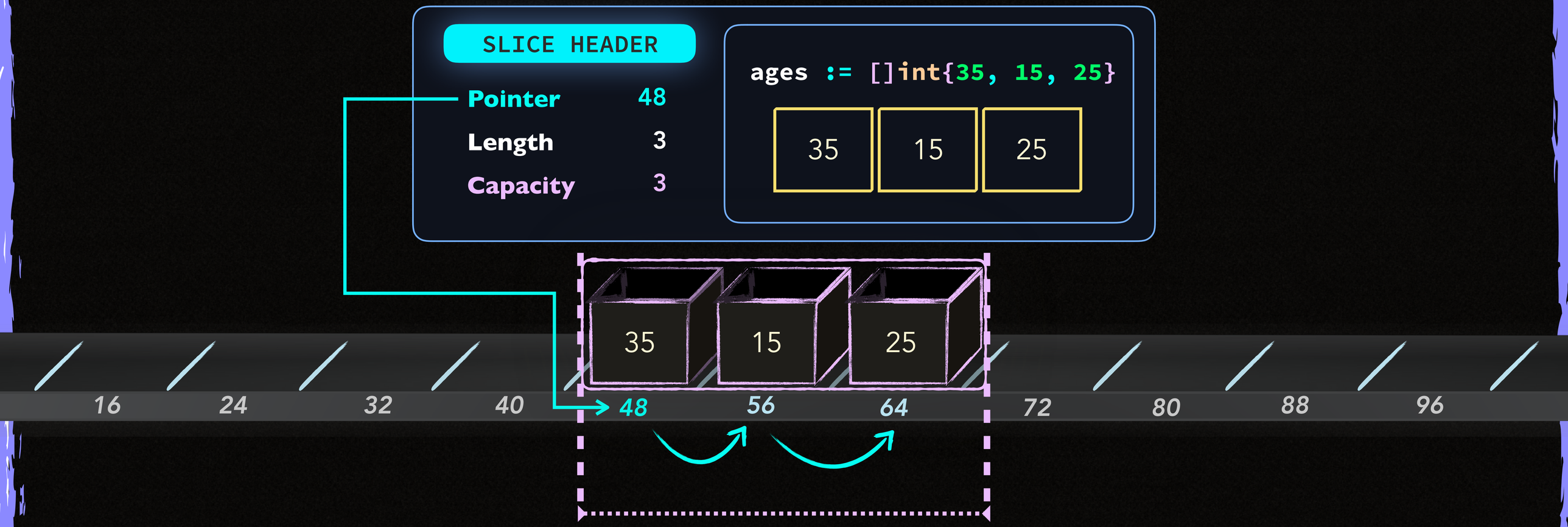
SLICE HEADER

A tiny data structure that refers to a slice's backing array



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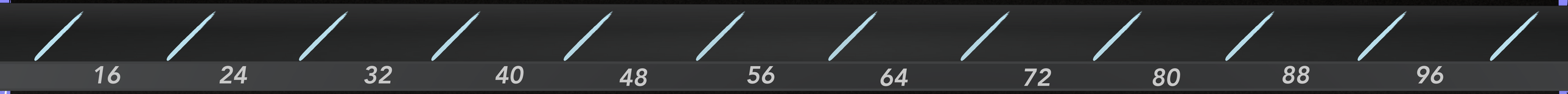
NIL SLICE

An nil slice doesn't have a backing array but it has a slice header



When you don't know whether a **slice** will ever have any elements

declare it as a nil slice

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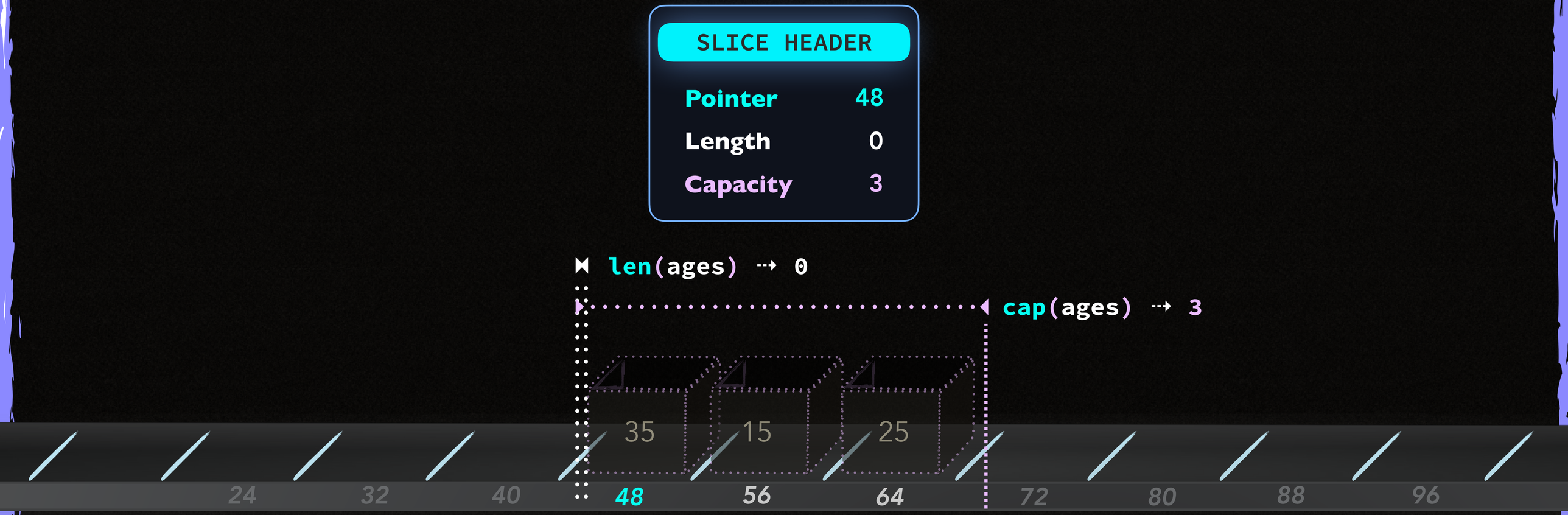
CAPACITY

An empty slice's length is zero but it has a backing array




```
ages := []int{35, 15, 25}
ages[0:0]
```

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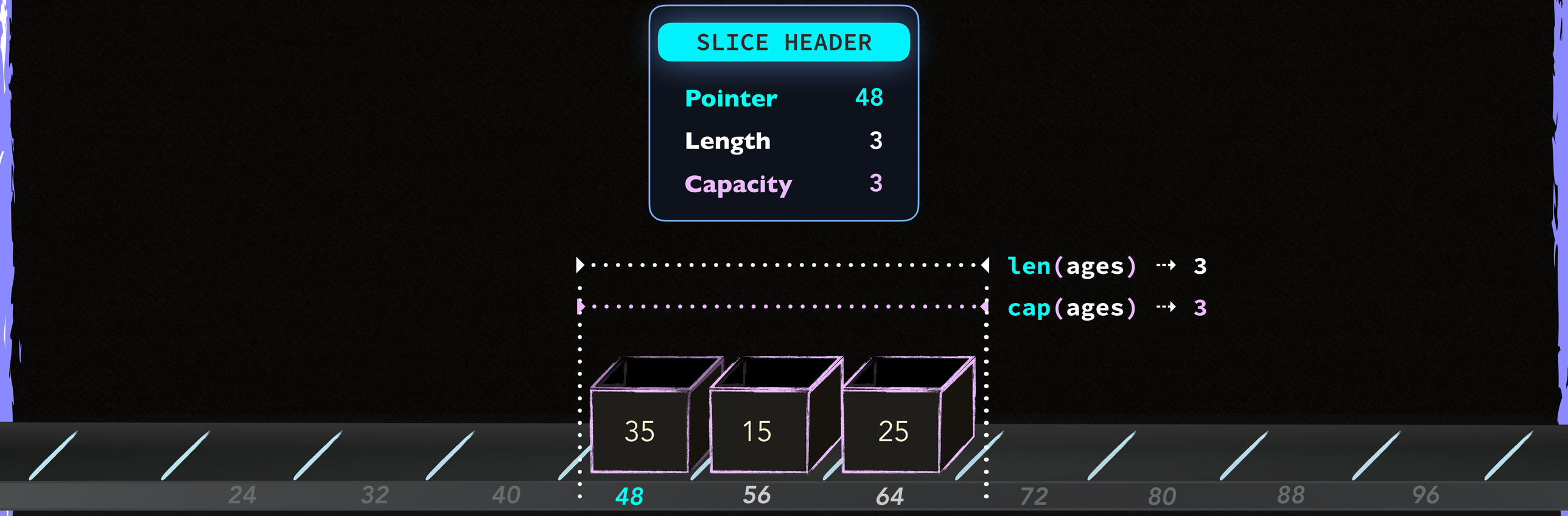
CAPACITY

Capacity determines how much you can extend a slice




```
ages := []int{35, 15, 25}
ages = ages[0:0]
ages[0:3]
```

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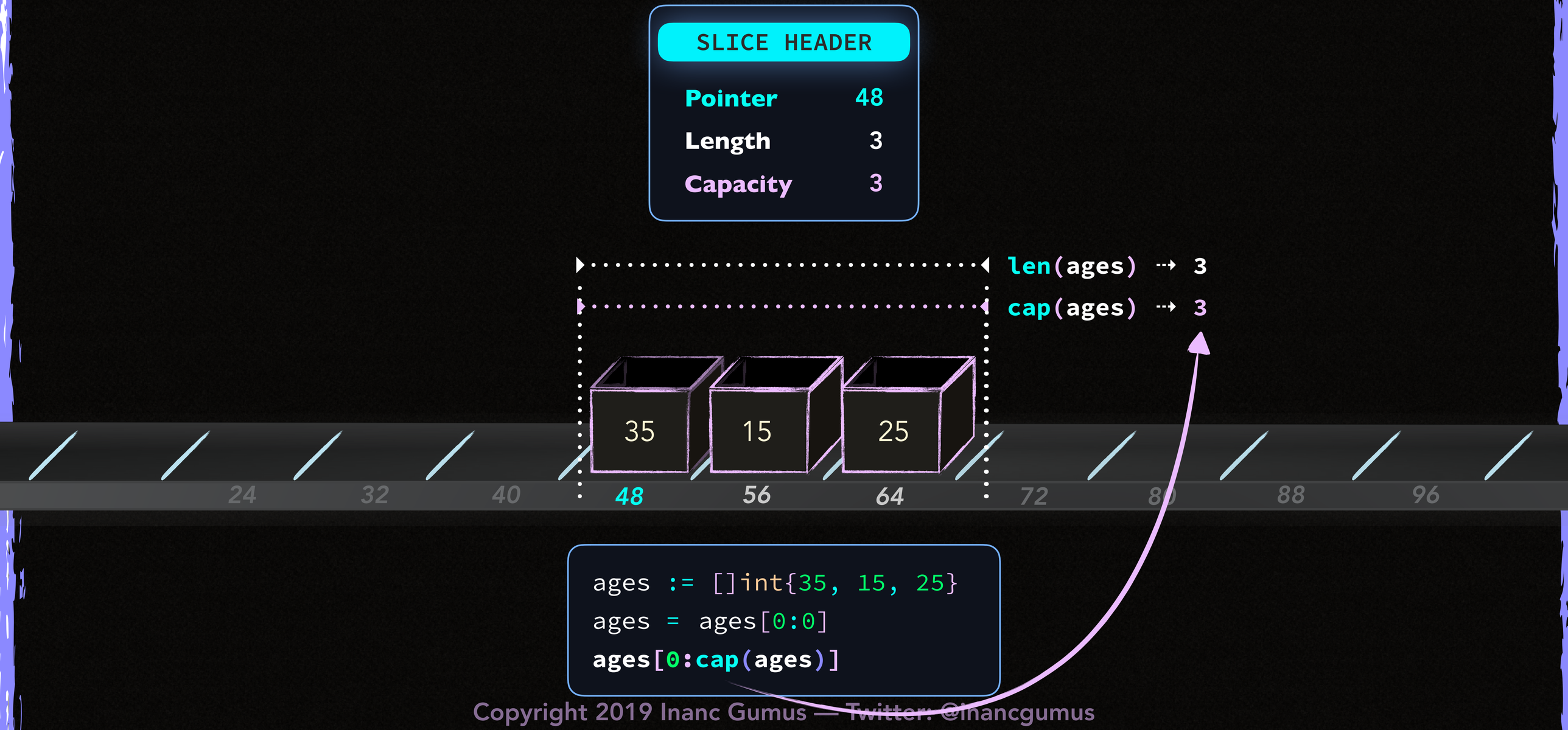
CAPACITY

cap function returns the capacity of a slice



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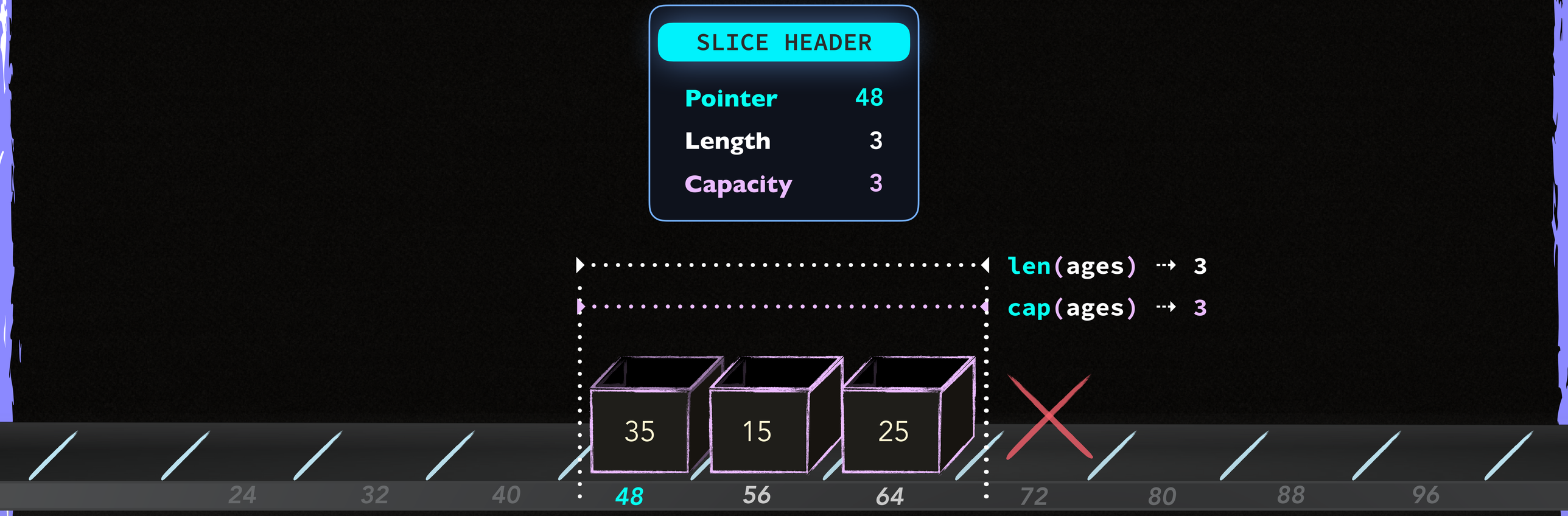
CAPACITY

You cannot extend a slice beyond its capacity




```
ages := []int{35, 15, 25}
ages = ages[0:0]
ages[0:cap(ages) + 1]
```

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MECHANICS OF APPEND

Append copies the elements of the previous array to the new array

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```

SLICE HEADER	
Pointer	48
Length	2
Capacity	2

SLICE HEADER	
Pointer	88
Length	3
Capacity	4

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MECHANICS OF APPEND

Assigns zero values to uninitialized elements of the backing array

```
ages := []int{35, 15}
```

```
ages = append(ages, 5)
```

SLICE HEADER	
Pointer	48
Length	2
Capacity	2

SLICE HEADER	
Pointer	88
Length	3
Capacity	4

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FULL SLICE EXPRESSIONS

```
sliceable := []byte{'f', 'u', 'l', 'l'}
```

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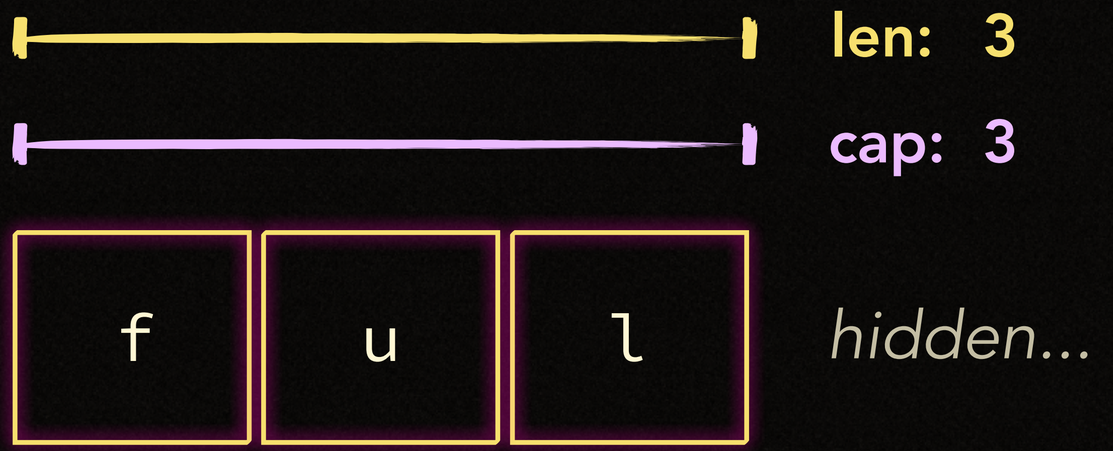
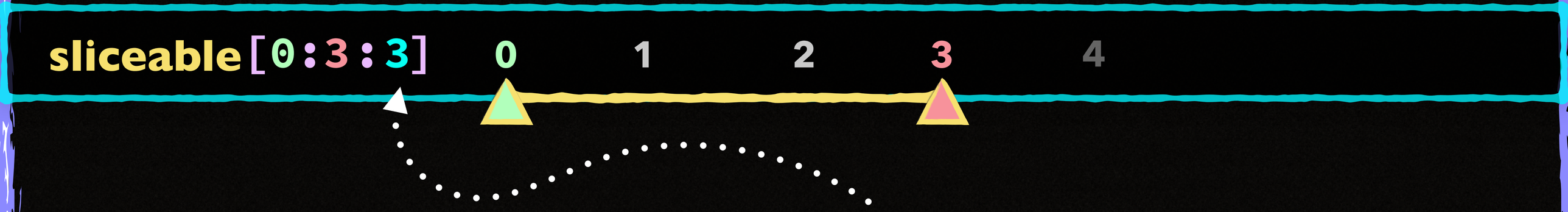
FULL SLICE EXPRESSIONS





think of the **capacity position** as
the element position in **the backing array**

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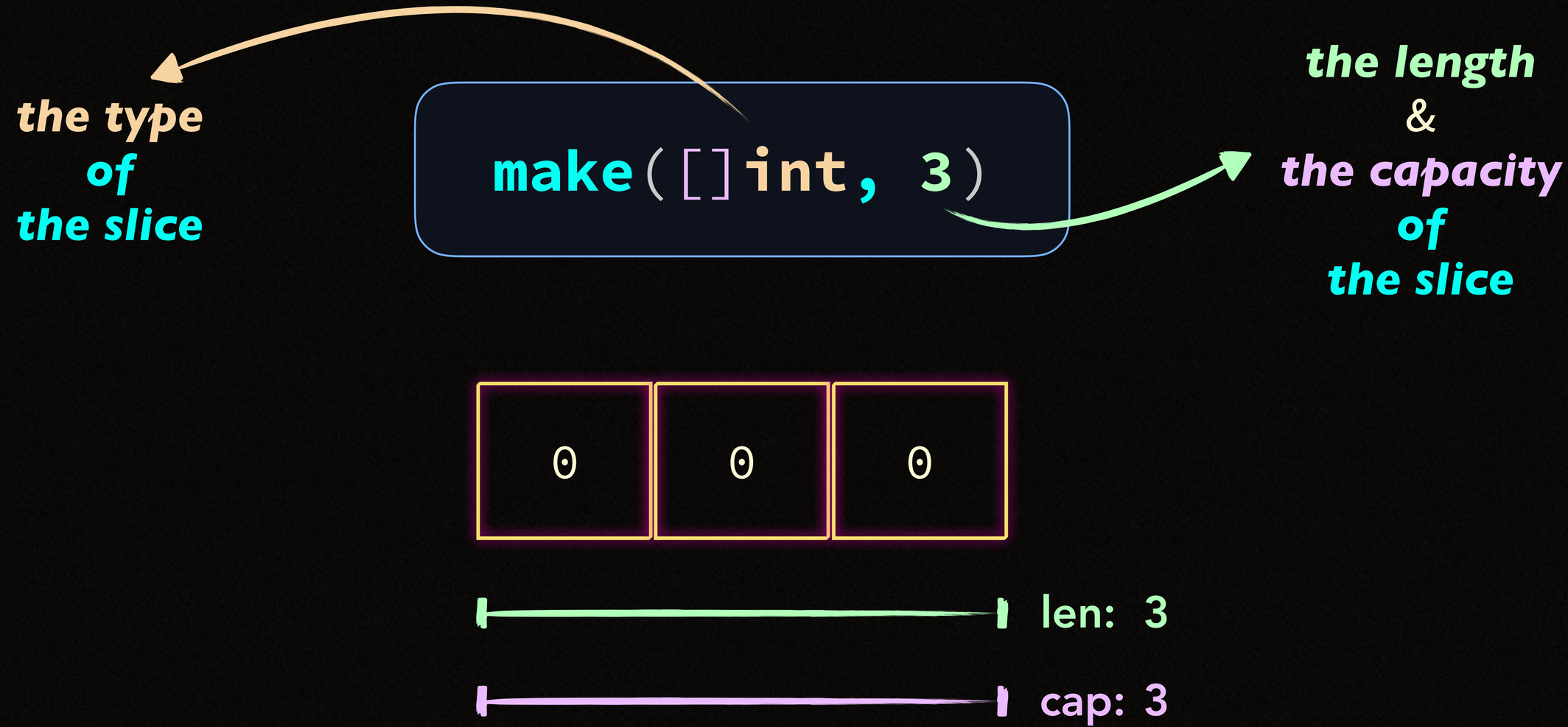
MAKE

make initializes and returns a slice with the given length and capacity



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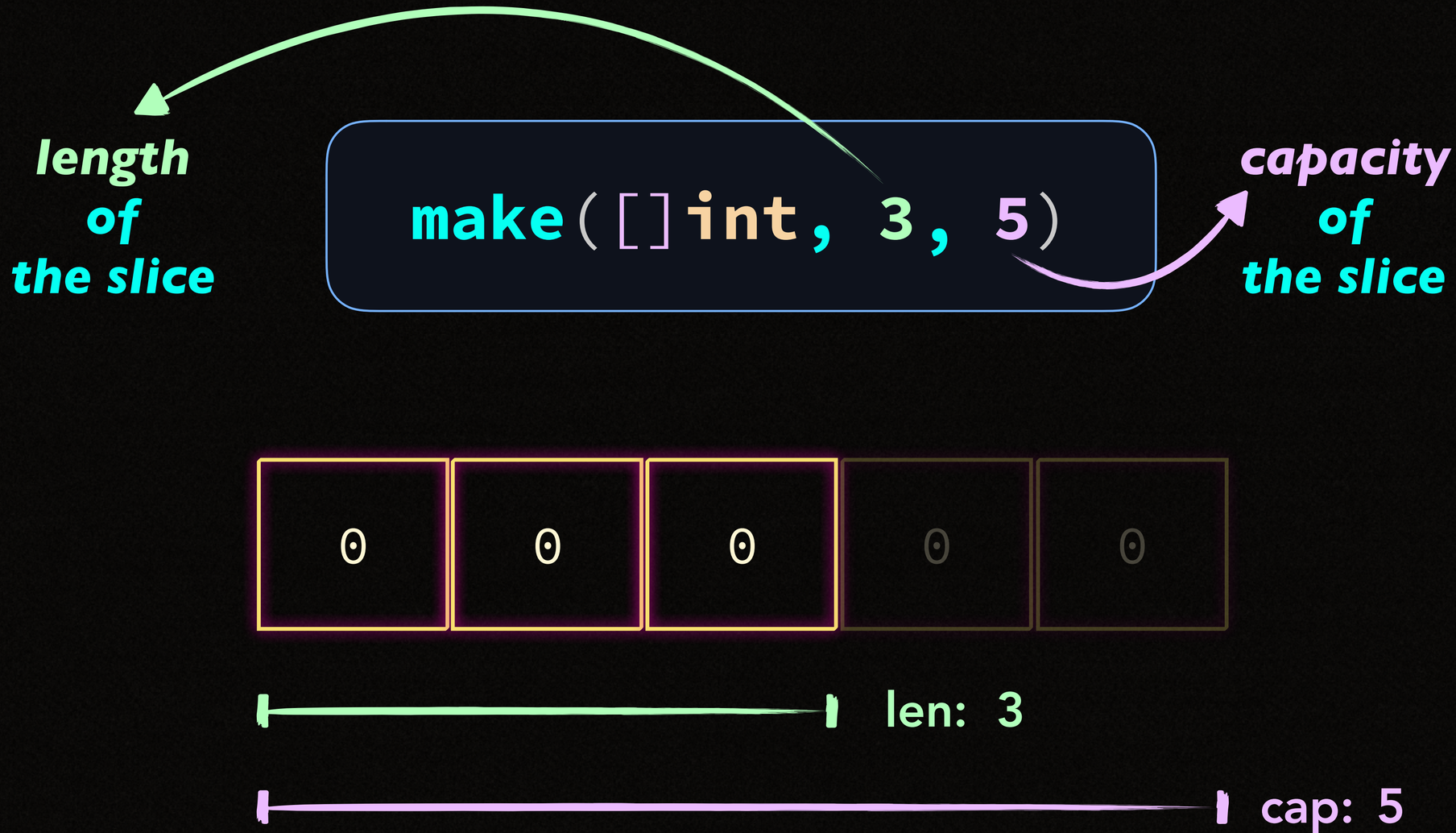

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MAKE

when the given length is 0, the make() will return a slice, ready to append

```
s := make([]int, 0, 5)
s  = append(s, 42)
```

ready to append

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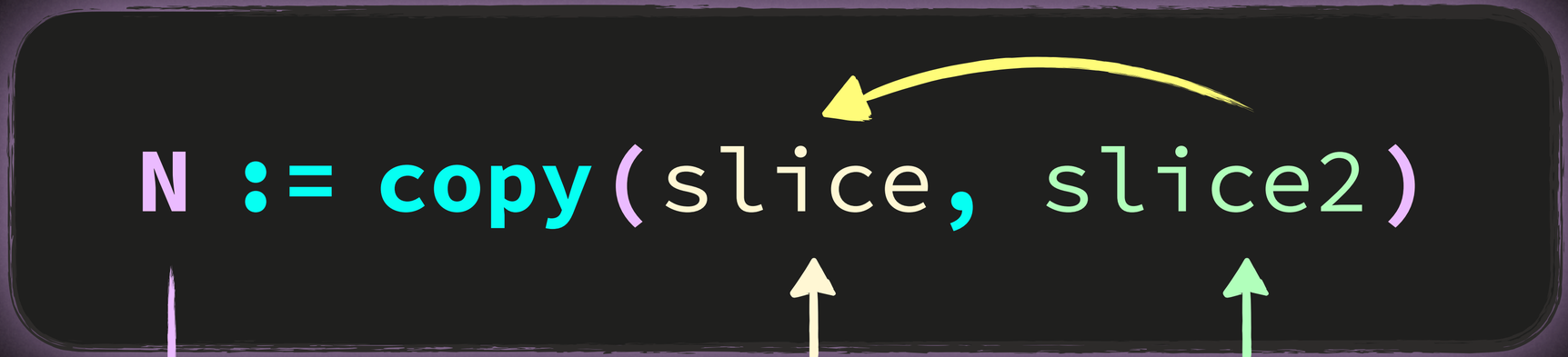
COPY

Copies the elements of a slice to another slice



returns the number of copied elements

destination slice

source slice

the element types of the slices should be identical

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PART IV

Composite Types

Arrays

Collection
of
Elements
Indexable
Fixed Length

Slices

Collection
of
Elements
Indexable
Dynamic length

String Internals

Byte Slices
ASCII & Unicode
Encoding & Decoding

Maps

Collection
of
Indexable
Key-Value Pairs

Structs

Groups
different types of
variables together

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